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Technical Report for Upper Snake River Biological Opinion
 # 1009.2700

Population Structure and Movement Patterns of Adfluvial Bull Trout (*Salvelinus confluentus*) in the North Fork Boise River Basin, Idaho

Master of Science Thesis

U.S. Department of the Interior
Bureau of Reclamation

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Master of Science Thesis

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September 2004

POPULATION STRUCTURE AND MOVEMENT PATTERNS OF ADFLUVIAL BULL TROUT (*Salvelinus confluentus)* IN THE NORTH FORK BOISE RIVER BASIN, IDAHO

Written by

Tammy D. Salow

A thesis

submitted in partial fulfillment

of the requirements for the degree of

Master of Science in Biology

Boise State University

The thesis presented by Tammy Dee Salow entitled "Population Structure and Movement Patterns of Adfluvial Bull Trout (*Salvelinus confluentus)* in the North Fork Boise River Basin, Idaho" is hereby approved by:

Advisor Date

Committee Member Date

Committee Member Date

Graduate Dean Date

DEDICATION

To my parents, Raymond and Sherry Hoem,

and to my husband, Mark,

for your guidance, love, and support.

ACKNOWLEDGMENTS

This work is funded by the U.S. Bureau of Reclamation and is a cooperative effort with the U.S. Forest Service and Idaho Department of Fish and Game. Special thanks are extended to: Rick Rieber, who helped me with equipment purchases, equipment installation, training, and project coordination; Kevin Meyer and Tony Lemanski, who helped me with ageing work and the neverending search for equipment; and Tim Burton for his help in training and study design for tributary monitoring. Additional gratitude to Bureau of Reclamation employees Steve Dunn, Steve Grabowski, Scott Lund, Jesse Chan, and Ted Day who filled in as boat operators and bull trout chasers. I would also like to extend thanks to the many employees from Bureau of Reclamation Pacific Northwest Regional office and the U.S. Forest Service Boise National Forest for their volunteer hours and enthusiastic support of my bull trout work.

I would like to extend a special note of thanks to my field crew members, Scott Vuono and Darren Cross for three years of hard work.

I would like to thank my graduate advisor and committee members, Drs. Peter Koetsier, Bruce Rieman and Jim Munger, for their guidance, editing, and analytical assistance.

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POPULATION STRUCTURE AND MOVEMENT PATTERNS OF ADFLUVIAL BULL TROUT (*Salvelinus confluentus)* IN THE NORTH FORK BOISE RIVER BASIN, IDAHO

Abstract

Bull trout (*Salvelinus confluentus)* were captured using four methods in distinctly different hydrologic conditions across the North Fork Boise River Basin in Southwestern Idaho. Trapping occurred between the months of April and October in years 1999 and 2000. Over 1,100 bull trout representing age classes 0+ - 9+ were sampled. Bull trout were found to move primarily at night and movement was related to temperature and flow fluctuations. Growth in bull trout appears to be greatest in age classes 2+ - 3+ fish that show movement in the river system. A possible relationship between year class strength of captured bull trout and annual flow and precipitation levels was observed. The North Fork Boise River adult (total length > 300 mm) post spawning population estimate was calculated to be 969 (s = 228) bull trout. The study results indicate that accessibility to migratory corridors and environmental conditions such as temperature and stream discharge play a major role in the movement and persistence of this population of fish.

Introduction

With growing concerns surrounding fisheries in the Northwest, the status of many native salmonid fishes such as bull trout *(Salvelinus confluentus)* have become a focus of interest. The status of Pacific Northwest bull trout populations have been under Federal agency review for over fifteen years. On September 18, 1985, the U.S. Fish and Wildlife Service (USFWS) published a notice of review that designated bull trout as a "candidate species". Several environmental groups petitioned Bull trout for listing under the Endangered Species Act as Endangered status in October 1992 throughout its entire range. In January 1994, Idaho Department of Fish and Game closed all Idaho waters to bull trout harvest except Lake Pend Orielle and the Lower Clark Fork River. In 1994, USFWS found that the 1992 petition was not warranted due to insufficient data regarding threats, status, and population trends of the Canadian and Alaskan population segments. However, the Columbia and Klamath basin population information was sufficient to warrant listing. Reasons for declining bull trout populations included habitat degradation and fragmentation, blockage of migratory corridors, poor water quality, poor past management practices, and the introduction of non-native competitors such as brook trout (*Salvelinus fontinalis*). The Columbia and the Klamath River Basin populations of bull trout were listed as Threatened status under the Endangered Species Act in June 1998 and the final rule was published in the Federal Register (USFWS 1998).

In compliance with the Endangered Species Act, the USFWS must develop a recovery plan with guidelines for management agencies to facilitate bull trout recovery. To address the mandate for a plan, Region 1 of the USFWS has coordinated recovery teams to outline recovery objectives for bull trout throughout its range. Since bull trout have a rather extensive range in the Columbia River segment, teams have been established by major watersheds or regions. The Boise Basin bull trout populations are located in the Southwest Basin recovery unit. The federal bull trout recovery team has outlined several important objectives for bull trout recovery. These were: 1) maintenance and restoration of the distribution of bull trout 2) maintenance and restoration of habitat for all life history forms 3) conservation of genetic diversity, and 4) implementation of recovery actions and assessment of their success (USFWS 2000).

Habitat conditions are one of the major factors cited in the 1998 listing as driving the decline of bull trout populations (USFWS 1998). Environmental conditions have strong influences on fish growth and development with most fish species being thermal conformers: generally classified as obligate poikilotherms or ectotherms (Barlow 1970, Brett 1971). Consequently, temperature and availability of forage has been shown to be the strongest forces behind physiological processes such as metabolism and assimilation that affect growth and reproductive success (Brett 1971, Winemiller and Rose 1992). Temperature has been found to be a driving factor in stream productivity, limiting dissolved constituents and levels of primary production; described by Brett (1971) as "the ecological master factor". Rieman and McIntyre (1993) describe variation in growth between different life history forms of bull trout related to availability of forage or the productivity of aquatic systems in which juvenile rearing occurs. Bull trout embryos and alevins have a long winter incubation and development phase which makes them particularly vulnerable to habitat changes in the spawning and rearing reaches (Fraley and Shepherd 1989). In addition, specific temperatures have been closely linked to migration timing, hatching success, and overall population distribution in bull trout (McPhail and

Murray 1979, Fraley and Shepherd 1989, Rieman and McIntyre 1995, Swanberg 1997, Rieman and Chandler 1999).

Life history theory proposes that different forms of salmonids (migrant versus resident) are responses to environmental mandates (Winemiller and Rose 1992). Thorpe (1994a) described the variation in life history forms as: "solutions to the problem of successful reproduction in a variable environment." Healy (1994) suggested that variation in life history is a response of salmonids to environmental conditions: a strategy to utilize a broad range of habitats as well as avoid environmental catastrophe. Thorpe (1994b) described responses by salmonids to environmental conditions as developmental flexibility, in which the organism inherits a range of responses and "chooses" or develops a certain response based on conditions of the environment during the developmental period. One conclusion that can be drawn is that environment plays a strong role in life history development: patterns of migration, and growth.

Bull trout have two distinct life history forms: migratory and resident (Rieman and McIntyre 1993). Migratory fish will leave spawning and rearing habitat (usually small tributaries) as one to four-year old juveniles (Fraley and Shepherd 1989). Juveniles migrate to larger rivers (fluvial) or lakes (adfluvial) for a period of one to three years (Pratt 1992). Migratory forms of bull trout reach sexual maturity at five to seven years of age and can live as long as 12 years (Fraley and Shepherd 1989). Migratory fish will leave the larger rivers and lakes as early as April to return to small tributaries to spawn (Fraley and Shepherd 1989). Spawning occurs from July-October and adult migrants return to the lakes or rivers over September-November (Rieman and McIntyre 1993). Not all bull trout spawn annually (Fraley and Shepherd 1989, Pratt 1992), although alternate year spawning patterns have been suggested as a strategy that has been used in other salmonids in response to energy availability (Thorpe 1994a). Resident forms of bull trout spend their life cycle in or close to the tributaries in which they were spawned and reared (Rieman and McIntyre 1993).

The sub-populations of bull trout in the Boise River Basin form one of the Southern-most distributions in the Columbia River basin (Rieman, et al. 1997). Although the Boise River Basin is fragmented by a series of dams (Lucky Peak, Arrowrock, Anderson Ranch), the sub-basins that feed Arrowrock and Anderson Ranch reservoirs support substantial habitat. In addition, Bull trout presence has been recorded throughout the Arrowrock Basin as well as migration documented in both Arrowrock and Anderson Ranch watersheds (Rieman and McIntyre 1995, IDFG unpublished data 1998, Flatter 2000). The work presented in this study focuses on large-scale environmental conditions and the influence that these conditions may have on bull trout populations in the Boise River Basin. Data is presented from the work conducted primarily in the North Fork Boise River drainage.

The study was designed to assess habitat, temperature, and flow conditions as they relate to bull trout presence or absence, densities, movement, and age class distribution on a large-watershed scale. Specifically, there were three primary objectives of the study: 1) assess environmental conditions which affect bull trout throughout their migration, rearing, and spawning habitat, 2) quantify size range of year classes of bull trout as they are captured throughout migration, spawning, and rearing habitat, and 3) assess the efficiency of various trapping methods used. The principle purpose of the work is to build upon the information collected by Flatter (2000) so that appropriate water and land use decisions can be made for management and conservation of bull trout populations in the Boise River system.

Study Area

The Boise River basin is located in southwestern Idaho and is a major tributary to the Snake River. Three dams are constructed on the upper Boise River system: Arrowrock, Anderson Ranch, and Lucky Peak dams. Lucky Peak Dam, an Army Corps of Engineers project, is located at the lowest elevation in the Boise river at river kilometer (rkm) 103 with a full pool elevation of 931 meters above sea level (msl). Arrowrock Dam, a U. S. Bureau of Reclamation project is 19 rkm upstream of Lucky Peak Dam on the main-stem Boise River. Arrowrock dam has a full pool elevation of 980 msl. Anderson Ranch Dam, also a U. S. Bureau of Reclamation project, is the most upstream of the three projects, located at rkm 81 of the South Fork of the Boise River with a full pool elevation of 1,272 msl. These reservoirs are operated collectively as one system for irrigation, flood control, and recreation.

The Boise River basin covers 5,700 km^2 of the granitic rock dominated landscape with elevations ranging from 931 m to 3231 msl. The upper Boise River includes three sub-basins: the North, Middle, and South Forks of the Boise River. The majority of this study occurred in the North Fork Boise River that joins the Middle Fork Boise River 30 km upstream from the South Fork/ Middle Fork Boise River confluence (Figure 1). The North Fork Boise River encompasses approximately 1,250 km^2 of the Boise River watershed area and extends up to 3,231 m in elevation. The Boise River system is fed primarily by snowmelt run-off with highest flows occurring in April-May and lowest in

September-October. Flows range from 11.33 m^3/s to over 198.28 m^3/s in the main-stem Boise River below the North and Middle Fork confluence. The North Fork Boise River flows range from 4.25 m^3/s to 113.28 m^3/s. Land uses in the North Fork watershed include grazing, recreation, and both commercial and individual timber harvest. The majority of the Boise River basin lies within Forest Service or Wilderness area boundaries.

Six of the eight major tributary watersheds (distinguished at the sixth hydrologic unit code level) were sampled in the North Fork Boise River. The watersheds sampled were Crooked River, Bear River, Johnson/Lodgepole Creeks, Big Silver Creek, Ballentyne Creek, and the Upper North Fork headwaters (a group of small streams: McLeod Creek, McPhearson Creek, upper North Fork Boise River, and West Fork Creek). Stream sites where electrofishing was used as a sampling method ranged from 1.44 m to 8.2 m in average wetted width and elevations from 1536 m to 2121 msl. Stream conductivities ranged from 48 ųS to 84 ųS with water temperatures ranging from -4ºC to 27 ºC.

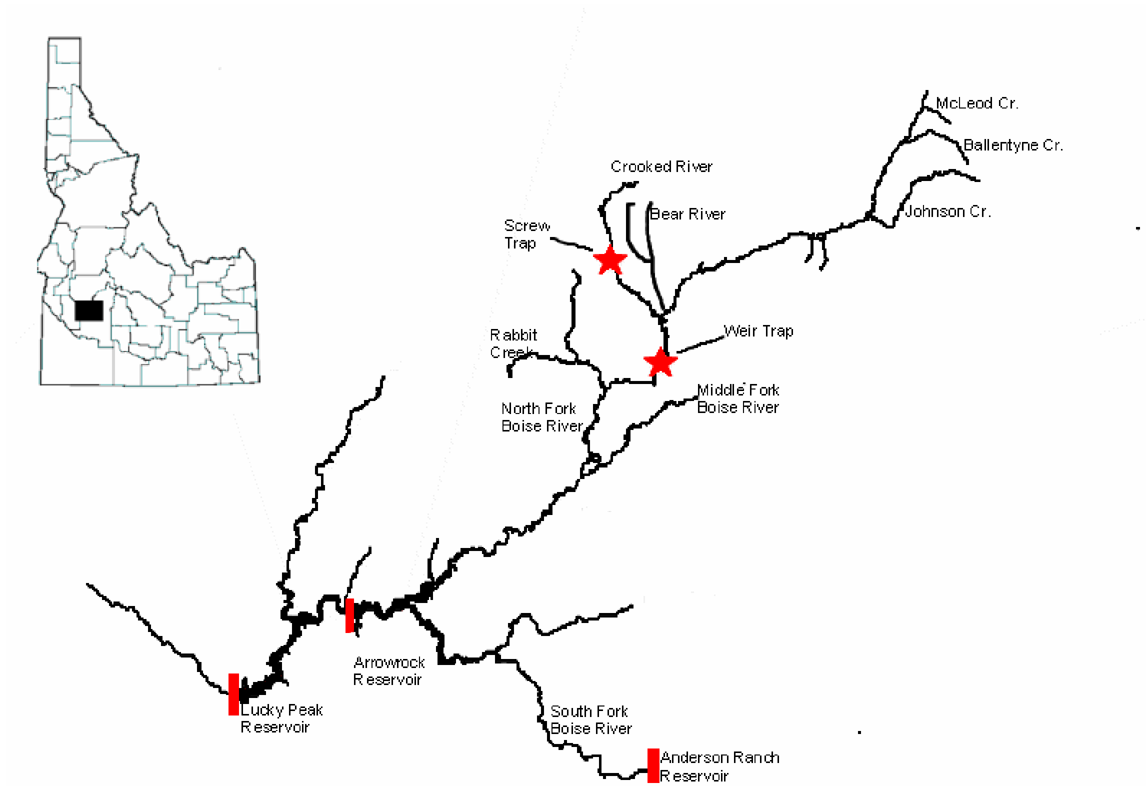

Figure 1. Boise River watershed emphasizing Anderson, Arrowrock, Lucky Peak dams, and North Fork Boise river watershed. Stationary trap locations are identified.

Methods

Fish Collection

Migratory forms of bull trout have been documented to move over 200 km (Fraley and Shepherd 1989, Swanberg 1997). To examine environmental effects on bull trout size and migration, four different capture methods were used across the migratory range of bull trout in the North Fork Boise River. Headwater streams, which are often associated with juvenile rearing and adult spawning, were sampled through electrofishing and habitat surveys were conducted. The Crooked River, a large tributary stream and possible migration corridor, was sampled using a rotary screw trap. The mainstem North Fork Boise River, the major migration corridor of the North Fork Boise River watershed, was sampled below all of its tributaries where bull trout have been documented using a steel frame picket-style weir trap. Finally, bull trout were captured by monofilament gill netting as a mitigation effort in Lucky Peak Reservoir. Reservoir work provides the opportunity to sample adfluvial bull trout in their overwintering habitat.

Headwater Streams: Spawning and Rearing Habitat

Two-pass backpack electrofishing was performed at 54, 100 m reaches and 50, 100 m reaches across the North Fork Basin in 1999 and 2000, respectively. Block nets were not used because access to many of the sites was by foot and packing them was not feasible. Smith-Root™ battery electrofishers were used and batteries changed every 3,500 to 4,000 operating seconds. Electrofishers were set between 500 and 900 volts and 30 to 40 Hz, depending on the size of the stream and conductivity. The North Fork and its tributaries have generally low conductivity, which averaged 53 ųS (range: 48 ųS - 84 ųS).

Generator electrofishers were not used during any part of the sampling due to designated Wilderness Area restrictions on motors in the higher elevation sites.

Crooked River Trap: Migration Corridor

On May 31, 2000, a 2.4 m cone width rotary screw trap was installed on the mainstem Crooked River kilometer 15 to be operated as flows and debris permitted. The trap was placed in a large pool following a run in the river. A screw trap was chosen because sampling would occur during high water containing a large amount of debris. Screw traps are situated on floating platforms and can sample in high water where substrate anchored traps or netting may be washed out or clogged with debris. The traps however, can be size selective: during low flows, large fish may escape a slowly rotating cone (Brian Leth, IDFG personal communication). The Crooked River screw trap was removed due to low flows on August 3, 2000.

North Fork Boise River Weir Trap: Migration Corridor

A 39.50 m long x 1.53 m tall steel picket style weir with upstream and downstream traps was operated across the full width of the North Fork Boise rkm 15. The trap was located adjacent to the U.S. Forest Service Barber Flat guard station from the end of August through October in years 1999 and 2000. The weir was constructed of 15, 3.05 m angle iron frames with steel conduit pickets spaced 1.25 cm apart. The weir had traps on both the upstream and downstream sides of the pickets so direction of fish movement could be determined. The trap was built following design recommendations and guidance from Russ Thurow (U.S. Forest Service, Rocky Mountain Research Station, personal communication). Operating time was planned during the post spawning migration of bull trout. Time and duration of the post-spawning run coincides with periods of lowest river discharge (USBR 2001a, Flatter 2000). Consideration was given to the flow information and a substrate anchored trap style was chosen. The trap design had been used by other agencies to target post spawning bull trout in a fluvial system, which was also the goal of my trap. The trap acted as a migration barrier for all fish > 1.25 cm in width (approximately > 200 mm total length for bull trout), capturing fish in traps as they moved upstream or downstream. Traps were checked, and pickets cleaned three to four times per day. To minimize predation inside the trap boxes on small fish, a pine bow was placed in one half of the box area to allow for cover (Russ Thurow, RMRS personal communication).

The North Fork weir withstood river discharge of over 5.66 m^3/s. Usually storm related peaks in discharge lasted less than 24 hours in duration. The trap was washed out by three to five day precipitation events that occurred in late October in both 1999 and 2000, elevating the North Fork flows over 7.08 m^3/s. To add strength to the trap, the design was altered in 2000 by adding 2.54 cm x 182.88 cm solid steel rod supports driven 30.0 to 40.0 cm into the substrate behind the supports of the trap. The steel rods allowed the trap to withstand higher water flows and were easier to install in rocky substrate than the steel fence posts used in 1999.

Lucky Peak Reservoir: Overwintering Habitat

All gill net work was conducted in Lucky Peak reservoir from April 17, 2000 to June 15, 2000 (as described by Flatter 2000). Experimental monofilament gill nets were set for 20-minute intervals to reduce incidence of mortality at sites where bull trout capture success had been high (Brian Flatter, personal communication). Nets were set during the daylight period from 8:00 to 17:00 hours four days per week. Nets were 30.5 m long by

1.25 m deep with four equal length panels. Each panel had one of four mesh sizes: 2.54 cm, 5.04 cm, 7.58 cm, and 10.12 cm. The nets had lead core bottom lines that followed the bottom of the reservoir and foam core top lines to maintain the verticle orientation in the water. Each net had 8 kg weights to anchor the bottom line and 20 cm diameter floats on the top line for location and retrieval. Nets were set perpendicular to the shoreline.

Catch rates were calculated for net hour and species. All captured bull trout were held in a 50-gallon live well with periodic water exchange until the end of each sampling day and then they were transported to Arrowrock reservoir, measured, tagged, and released. The netting project was part of a continuing effort to mitigate for entrainment of bull trout into Lucky Peak reservoir as documented by Flatter 1999. Bull trout were netted in April through May when they are anticipated to be staging below the dam in preparation for the spawning migration. The effort is a requirement of Endangered Species Act consultation between the USFWS and USBR.

Fish Tagging and Handling

All fish captured were identified to species and enumerated. Total length (TL) was recorded for all game species. Collected bull trout were anesthetized using diluted tricaine methanesulfonate (MS-222) (approximately 100 mg/L). When a fish was considered anesthetized (could not right itself) its total length and weight was recorded. A scale sample and fin clip were taken, and the fish was scanned for Passive Integrated Transponder (PIT) tags (AVID computer corporation, Norco, CA 1999). All bull trout > 100 mm TL which did not carry tags were tagged with 2.5 mm x 14 mm, 125 kHz PIT tags in accordance with instruction from Idaho Department of Fish and Game personnel (Russ Kiefer IDFG, personal comm.). Bull trout were held and monitored in live wells until full recovery (minimum 15 minutes), and then returned to the vicinity of capture. If bull trout were captured in stationary traps, direction of migration and time of capture was noted. Fish capture was recorded by date and time of trap check. Groupings and pairs of fish were noted. All recaptured bull trout were measured and weighed so that data for growth over the time period for mark and recapture could be recorded.

Collection of Environmental Variables

Habitat Surveys at Electrofishing Sites

Habitat condition was measured following modified R1/R4 methods of the USFS as described in Burton (1999). Stream segments were randomly selected across the North Fork watershed with some deference to accessibility (sites shown in Appendix E: Figure 1.E). Most sites were accessible only by foot and randomly selected sites with cliff walls that could not be reached by hiking were not sampled. Habitat was measured using to the following methodology:

Water was categorized as either slow or fast types and had differing measurements taken at each type. Aspects of slow water that were measured were: thalweg length, maximum depth, mean depth, crest depth, averaged wetted width, available cover area, and percent fines.

Thalweg Length: thalweg length was measured from the crest of the slow water unit (usually the most shallow downstream end of the depression) to the forming feature of the slow water unit.

Maximum Depth: maximum depth was the greatest depth measured in the slow water type.

Average Width: average width was taken at the depth of the pool that was the mean of the crest and maximum depth, and was the wetted width of that area.

Mean Depth: mean depth was taken at the area where average width was measured. Depths were measured at approximately ¼, ½, and ¾ of the channel width and the average was calculated by dividing the sum by four (to account for zero depth at the banks).

Available Cover Area: cover was categorized as either large wood debris, overhanging vegetation, or undercut banks. All cover types had to be at least 0.30 m in width to be measured and capable of providing refuge to fish. All aggregates of wood were measured for combined total area (each piece was added to calculate a combined total). Each habitat feature was measured by length and width with area calculated.

Percent Surface Fines: were estimated at each slow water pool tail. Percent surface fines were measured using a 100-intersection grid. Field staff measured the percent of the wetted substrate area of pool tail that is made up of fine particles (sand/silt less that 6 mm) by randomly tossing the grid. The cross section of the pool tail was sub-divided into 3 segments: right, middle, and left. The grid was tossed and percent fines were tallied in the three sections of each slow water unit. After the grid had rested on the bottom, a piece of Plexiglas (25 cm x 25) was used to view the bottom substrate within the grid. This prevented glare and surface agitation from disrupting the viewer. The grid intersections were counted only where substrate was smaller than 6 mm.

Length, average width and depth were the three measurements taken for fast water types. Measurement methods of fast water type variables were the same as for slow water types. A two-meter pole marked to the tenth meter is used to measure all habitat variables. Field staff were trained each year for habitat measurement under guidance from Tim Burton, USFS.

Temperature and Flow Measurements

Three methods were used to collect and validate temperature readings in the field. Water temperature and conductivity readings were taken at each electrofishing site at the time the sites were sampled to appropriately set electrofisher voltage and pulse widths. In addition, water temperature was recorded every 2 hours at 12 locations in North Fork tributary streams across a range of elevations and stream sizes by Tidbit™ (Onset Computer Corporation, Pocasset, MA 1999) temperature loggers (sites shown in Appendix A: Figure 1.A). Finally, data was also collected electronically from five USBR Hydromet stations. Remote access from Hydromet stations gives data for daily-accumulated precipitation, mean daily flow, and temperature. The five Hydromet stations were located near Twin Springs (BTSI), Atlanta (ATLA), Arrowrock Dam (ARKD), Anderson Ranch Dam (ANDD), and Lucky Peak Dam (LUCD), Idaho (USBR 2001a).

Age Class Determination

Scales were collected and processed following methods described in Flatter (2000). Bull trout scale samples were collected from the section of the fish's body posterior to the dorsal fin and dorsal of the lateral line. All scales collected were mounted on clear 2.54 cm x 10.16 cm x 0.05 cm acetate slides and pressed with a Carver heat press at 10,000 PSI, 110°C, for 35 seconds. Impressions were then projected using a microfiche reader. Annuli were counted by three individual readers. Each reader aged the samples twice to calculate average percent error for the individual reader and to calculate error between the readers (Chang 1982). Two methods were used to assign age to fish by length. First, ages for each length class were estimated for bull trout based on regressing age on length. Though lower in accuracy, regression allowed for distinct segregation of age classes. The mean difference between model age at length values were used to show the range of each length class, and bull trout were assigned to age classes based on their lengths. Alternatively, bull trout were assigned to age classes using the mean length at age and proportion of overlap of fish between age classes from the actual length and age data. The second method was more accurate because it used actual data, but as fish were aged to older classes (7+ or older), overlap between year class and lengths complicated differentiation of age groups. Scale aging work was validated by comparing age estimates of otoliths to those of scales from capture mortalities.

Data Analyses

Analyses were conducted separately for each of the four capture-methods due to the limitations associated with each method and the variation of environmental data collected in the different locations. Additionally, population parameters such as juvenile density (fish/area sampled), recruitment (estimate of the number of fish that could have moved through the area sampled given the trap efficiency), or a total population size were calculated. Methods and assumptions used for each population parameter are listed by the capture method for which they were applied.

Growth was determined for all methods by comparing changes in total length and weight for recaptures and was distinguished for annual and seasonal patterns for adults and juveniles. Bull trout captured in the reservoir and recaptured at the weir the same year were shown to have migrated, however spawning was not documented.

Temperature was collected at 12 thermographs plus Hydromet data was used for years that the data was not collected prior to the initiation of the study. To validate use of Hydromet gauge data, graphs were compared for concurrent years across a range of elevations. Appendix A (Figures 2.A – 3.A) show Hydromet gauge data as compared to thermograph data at various locations across the Boise River Basin. Appendix A (Figure 5.A) shows spring discharge for the North and Middle Forks of the Boise River in years 1999 and 2000. Differences in discharge levels may account for some of the variation in catch rates and model results between years.

Headwater Streams: Spawning and Rearing Habitat

All statistical analyses were conducted with SAS Version 8 statistical software (SAS 1999). Statistical analysis was conducted on the basin-wide data for presence and absence groups at all sites sampled by electrofishing. Separate analysis was conducted at presence sites only with densities of bull trout. Independent variables for densities or presence/absence were habitat variables collected at each site (Appendix B: Table 1.B). Stepwise linear discriminant function analysis was used to identify best habitat predictors of presence and absence. The best fitting linear discriminant function was then used to show error rates for prediction of presence or absence for all sites sampled.

Density analysis was conducted using multiple regression for sites where bull trout were present. Dependent variables calculated from the two-pass estimates and variances were used (Everhart and Youngs 1981). These were: total catch of bull trout (all fish captured in the stream), density (bull trout/m^2), variance of the density for each site (s (density)), and catchability (probability that the fish would be captured using the effort applied) (Appendix B: List 1.B). Independent variables used were selected from the habitat variables at bull trout presence sites (Appendix B: Table 1.B). To reduce the independent to dependent variable ratio, I removed all highly correlated variables (Appendix B: Tables 2 - 11.B) and those variables that were used to calculate another variable (e.g. length X width were used to calculate the area for cover). Best models were fit from stepwise selected variables, and assumptions were tested.

Densities of bull trout were estimated by stream-site using Seber - LeCren two-pass depletion population estimation methods over the average wetted stream area for each electrofishing site (Everhart and Youngs 1981).

The Seber-LeCren equation used for the two-pass estimate was:

$$N = \frac{Ç^2}{Ç - \dot{C}}$$

and for catchability was:

$$1 – q = \dot{C} / Ç$$

Where: Ç = Catch of fish in first pass

$\dot{C}$ = Catch of fish in second pass

N = the estimate of fish in the stream reach

q = the catchability constant (probability the fish would be caught using the study effort applied)

Additionally, variances were estimated by:

$$V(N) = \frac{Ç^2\, \dot{C}^2\, (Ç + \dot{C})}{(Ç - \dot{C})^4}$$

$$V(q) = \frac{\dot{C}\, (Ç + \dot{C})}{Ç^{3}}$$

Crooked River Screw Trap: Migration Corridor

Linear regression models were used to show the relationship between the number of bull trout captured per day and temperature (Crooked River rkm 21.5) that was recorded. Several manipulations of the data were used to best fit the patterns shown in the raw data.

The overall trend of the temperature data was positively correlated to date. To remove the trend, temperature and catch per day were regressed on date. Residuals were then used to examine the association of temperature and catch per day. Catch residuals were used for the dependent variable and temperature residuals used for the independent variable.

The trap was checked daily, and marked fish were released 100 meters upstream of the trap to examine the efficiency of capture of the trap. Marked fish that were recaptured were noted, and weekly efficiency was calculated by dividing the number of recaptured fish by the number of marked fish. Recruitment was estimated by taking the total number of bull trout captured in a week minus the weekly recaptured bull trout and dividing by the weekly trap efficiency (as described in Madden and Lewis 1999).

Weekly recruitment equation:

$$R = \frac{N - \check{N}}{E}$$

Where: R = Number of bull trout estimated to move through the trap in a given week

N = Total number of bull trout captured and marked in a week

Ň = Number of marked bull trout that were recaptured

E = Trap efficiency (number of fish marked divided by the number recaptured for the week).

Total recruitment was calculated by summing the weekly recruitment estimates. If no bull trout were recaptured during a week, the mean efficiency of the trap from the duration of operation was used for the weekly estimate. Mean efficiency was calculated with the following equation (Zar 1999):

$p = X/n$

where

p = proportion of population recaptured

X = number of fish recaptured

n = number of fish marked

Error using standard error of the mean efficiency. The equation used for calculation of standard error was (Zar 1999):

SE = SQRT [(p*q)/n-1]

where p = proportion of population recaptured

q = 1-p

n = number of fish marked

The upper and lower bounds of the recruitment were then calculated from the efficiency estimate using the standard error.

North Fork Boise River : Migration Corridor

Methods of statistical analyses used for the weir data were similar to those used for the rotary screw trap data but with several notable differences. Important differences in the trap data were time of year of operation (fall for the weir versus spring for the screwtrap) and flow data was used in addition to temperature as an independent variable in all weir analyses. Additionally, bull trout were separated into juvenile (< 300 mm TL) and adult (> 300 mm TL) size classes for catch per day independent variables. Finally, separate scenarios were analyzed for temperature, flow, and precipitation relationships: one to examine the season variation and one to examine annual variation.

To examine seasonal variation in catches, multiple regression models were created using catches per day as dependent variables and flow and temperature as independent variables. The overall trends in mean daily temperature and flow were negatively correlated to date. To remove of the trends, models were created with catch per day, flow, and temperature regressed on date. Residuals were then used to examine the effects of temperature and flow on catch per day. To examine the temperature and flow influence, numerous multiple linear regression models were created using combinations of a five-day and ten-day delays of the raw, average, and residual catch data of juveniles separately from adults as the dependent variables.

Temperature and flow were modeled values from the Hydromet BTSI gauge data and verified by the temperature datalogger in situ (see Appendix A: Figure 3.A). Temperatures at the weir trap and gauge BTSI were consistently correlated with three-degree temperature differences between BTSI and the logger set at the Barber Flats weir. Flows from the North Fork constitute 31% of the BTSI flows as calculated from 1947-

1950 Hydromet data (USBR 2001a) comparing both systems and they fluctuate at similar levels (see Appendix A: Figure 4.A).

Effects of water year (determined by accumulated precipitation and mean spring discharge) was examined for bull trout captured at the weir by using year class strength. Age was assigned to bull trout based on length from the scale age work. The strength of each year class was considered the number of bull trout representing each year that the fish would be age 0+. The independent variables used were accumulated precipitation for that year (sum of daily precipitation November 1- March 31), spring flow (average daily mean April 1-July 31), and temperature[*]. Data for flow, precipitation, and temperature were used from Hydromet gauges BTSI and ATLA (USBR 2001a). Data were used for the analyses that included the years before the study data were recorded (before 1999) so that year classes of bull trout could be compared with environmental data collected from 1989 to 2001.

The year class strength analysis assumes constant mortality with each year of life, which most likely is not valid. Additionally, sample size for each age class varies with natural mortality, capture efficiency of the weir trap, and the error associated with the regression model used to assign fish to each age class (this analysis was particular to the weir trap captured bull trout). The magnitude of error associated with the model work was quite large due to the assignment of age classes and assumption of constant mortality rates at each year class. Consequently, I chose not to model data as it may misrepresent actual trends. Raw data is reported to illustrate the possible trends which were observed.

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[*] Water temperature was available only for years 1998, 1999, and 2000. June mean air temperature was used as there is no significant difference between June air and water temperature

A total population size was estimated for weir captured bull trout (total length > 300 mm from Flatter 1998) by mark-recapture techniques as shown in Sheaffer et al. (1996).

Mark-Recapture population equations:

$$\check{N} = \frac{nt}{s} \quad \text{and variance of N is} \quad V(\check{N}) = \frac{t^2 n (n - s)}{s^3}$$

Where $\check{N}$ = estimate of population size

t = number of bull trout marked in 1999

n = number of bull trout marked in 2000

s = number of recaptured bull trout

This equation assumes no immigration, emigration, mortality, or alternate year spawning. However, since only the 1999 post-spawning adults are being estimated, mortality, alternate year spawning, and emigration from the group is most likely similar between years. To illustrate a range of estimates that incorporate immigration and tag loss, the changes that would occur in marked and recaptured fish under varying levels were considered. Data were not available which reflects the actual rate of maturation or "immigration" into the population. Arbitrary values of immigration were used varying from 20 – 60 % annually. I believe that 40 % immigration for 2000 could most closely reflect the actual immigration (from 2001 recapture data not incorporated into this report), but a wider range was chosen for illustration purposes.

Lucky Peak Reservoir: Overwintering Habitat

The dependent variables Catch Per Unit Effort (CPUE), total fish caught per day and bull trout caught per day were used to create environmental models for reservoir captures. Independent variables used were daily and weekly reservoir elevation, precipitation, and discharge in both Lucky Peak and Arrowrock reservoirs as recorded by Hydromet gauges

ARKD and LUCD (USBR 2001a). Data were analyzed for both total daily catch per day of and CPUE of all species combined and for bull trout CPUE and daily catch separately.

CPUE was calculated for each day and averaged for the week. CPUE was calculated by recording the total net set time (hours) and dividing total fish and bull trout catch for the day by the total net set time.

$$CPUE = \frac{Nt}{Nf}$$

Where: Nt = Total net set time

Nf = number of fish caught

Results (Pooled Data)

Total Fish Capture

The combined fish capture during July 1999 to October 2000 was 3806 fish representing six genera and nine species (Table 1). A total of 1183 bull trout were captured and 1039 were tagged in all methods over the two years of the study. The majority of fish captured were bull trout, which was the target species. Total catch data does not reflect actual species contribution of the Boise Basin fishery. Catch composition by method and year is listed in Appendix C: Table 1.C.

Table 1. Total number of fish collected from all sites over the study years 1999 and 2000.

Species	**1999**	**2000**
Bull trout (*Salvelinus confluentus)*	467	664
Rainbow trout *(Oncorhynchus mykiss)*	319	575
Mountain whitefish *(Prosopium williamsoni)*	171	168
Brook trout *(Salvelinus fontinalis)*	38	33
Westslope cutthroat trout *(Oncorhynchus clarki)*	14	29
Sculpin spp. *(Cottus spp.)*	60	353
Largescale sucker *(Catostomus macrocheilus)*	12	816
Northern pikeminnow *(Ptychocheilus oregonensis)*	32	31
Bridgelip sucker *(Catostomus columbianus)*	0	24
Total	**1113**	**2693**

<u>Age and Growth</u>

When the lengths of bull trout captured by each method were compared, the sizes of fish captured at different methods significantly differed from each other and the fish could be grouped by the method of capture (ANOVA, $p < 0.01$). Consequently, age by length modeling was conducted separately and also combined for each method. Linear regression models showed positive relationships between the age classes and increasing lengths of fish, though the slopes differed by method of capture. Weir captured bull trout showed the greatest range of ages and also had the largest sample size. However, the model slope for weir captured bull trout was much less than for tributary captured bull trout (0.37 for the weir versus 0.47 for the tributary fish). Slope is the increase in age divided by the increase in length for the models. The difference in slope most likely reflects the higher growth rates (large increases in length for smaller increases in age) shown in juvenile bull trout (see Discussion). A comparison is made of the age by length data from reported literature and all length models and data and is shown in Table 2. Mean lengths for each age class are reported for the combined regression model in Table 3 and actual data in Table 4 (regression models shown in Appendix D: Tables 2-6 D, Actual data for age class and lengths in Figure 1.D).

Table 2. Mean length at age comparison of reported literature values and calculated models from Boise Basin bull trout capture and aging work.

Basin	**Source**	**Age Class (lengths in mm)**						
		0	**1**	**2**	**3**	**4**	**5**	**6**
Metolius	Pratt 1991*	54	111	191	299	459	652	828
Flathead-upper	Fraley and Shepard 1989	66	121	196	292	385	475	566
Flathead-lake	Fraley and Shepard 1989	68	129	204	291	384	472	566
Flathead-NF	Fraley and Shepard 1989	73	117	165	301	440	538	574
Flathead-MF	Fraley and Shepard 1989	52	100	165	297	399	488	567
Flathead-NF**	Fraley and Shepard 1989	73	117	155	228	-	-	-
Chester Morse Lake	Conner et al. 1997	78	142	242	301	341	368	437
Flathead-Lake	Brown 1971°	71	140	208	323	452	594	724
Priest Lake	Bjornn 1961°	41	114	183	341	424	516	605
Boise River-NF	Salow 2001[1]	97	123	165	213	266	326	392
Boise River-Tributaries	Salow 2001[2]	62	100	146	202	266	340	422
Boise River-Mainstem	Salow 2001[3]	*64	109	174	220	261	335	394

* Linear regression model values reported
** Juvenile size fish only
° Citations are taken from Conner et al.

[1] Denotes combined model
[2] Denotes tributary fish from electrofishing work
[3] Denotes actual mean lengths at age from scale aging work, *age 0 is mean length from length frequencies

Table 3. Percent of bull trout comprising each age class (as determined by age at length regression analysis) when the length classes are used for bull trout captured from all four methods.

Age and Length Classes			**Electrofishing**		**Weir**		**Screw Trap**	**Reservoir Netting**
Age class	**Mean length (mm)**	**Length range (mm)**	**% of bull trout 1999**	**% of bull trout 2000**	**% of bull trout 1999**	**% of bull trout 2000**	**% of bull trout 2000**	**% of bull trout 2000**
0+	87.35	<103	18.7%	43.2%	0.0%	0.0%	0.0%	0.0%
1+	122.9	104-142	49.8%	22.1%	0.0%	0.0%	1.8%	0.0%
2+	164.7	143-187	23.2%	23.6%	2.1%	0.7%	43.9%	0.0%
3+	212.5	188-243	5.9%	9.5%	57.9%	43.8%	54.4%	0.0%
4+	266.4	244-294	0.5%	1.0%	40.0%	55.5%	0.0%	4.3%
5+	326.3	295-357	0.5%	0.1%	32.5%	30.9%	0.0%	0.0%
6+	392.3	358-426	1.0%	0.0%	37.7%	22.4%	0.0%	13.0%
7+	464.5	427-500	0.5%	0.0%	19.3%	33.6%	0.0%	60.9%
8+	542.6	501-581	0.0%	0.0%	5.3%	9.9%	0.0%	17.4%
9+	626.9	582-668	0.0%	0.0%	3.5%	2.6%	0.0%	4.3%
10+	717.3	669-762	0.0%	0.0%	1.8%	0.7%	0.0%	0.0%

**Note that weir age classes are calculated for percent contribution for juvenile (<300mm) and adult (>300mm) lengths

Table 4. Length ranges and overlap of actual scale age by length data for assignment of age classes

Age Class	Mean Length (mm)	Range (actual data)	N (sample)	N(overlap)	Percent overlap (younger)	Percent overlap (older)
0+	**64.1	**30-80	**51	0	N/A	N/A
1+	109	90-175	45	54	74.07%	25.93%
2+	174	98-290	82	202	86.14%	13.86%
3+	220	91-370	170	333	49.85%	50.15%
4+	261	115-530	175	268	62.69%	37.31%
5+	335	183-505	100	139	70.50%	29.50%
6+	394	216-570	46	54	62.96%	37.04%
7+	492	340-715	24	38	60.53%	39.47%
8+	478	168-660	14	7	57.14%	42.86%
9+	550	520-570	3	0	N/A	N/A

**fish < 90 mm in length were unable to retrieve readable scales, data is from mean and range of length frequency of tributary samples at age 0+.

Growth

Table 5 and Figure 2 show the average growth per day for marked and recaptured bull trout. Juvenile size (< 300 mm TL when marked) bull trout that were moving from the screw trap to the weir trap during the summer season had greatest daily growth. Greatest annual growth was in juvenile size bull trout that were captured moving downstream in 1999 and recaptured (possibly following the first year spawning) in 2000. Adult sized (> 300 mm TL when marked) bull trout showed the least seasonal and annual growth patterns.

Table 5. Total growth and average growth per day combined for marked and recaptured bull trout from study years 1999 and 2000 for all sites sampled.

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Juvenile recaptures (< 300 mm total length at mark date)

Site marked	Site recaptured	# Bull trout	Average growth in mm (standard deviation)	Average days between mark and recapture	Average growth per day (mm)
Headwaters	Headwaters	1	25 (0)	331	0.08
Headwaters	N. F. Boise	1	13 (0)	42	0.31
Headwater	N. F.Boise	2	62.5 (36.00)	394	0.16
N. F. Boise	N. F. Boise	3	90.3 (22.20)	371	0.24
Screw Trap	N. F. Boise	2	56.5 (8.90)	103	0.55
Adult recaptures (> 300 mm total length at mark date)					
Headwater	N. F. Boise	1	46 0	418	0.11
N. F. Boise	N. F. Boise	16	52.37 15.63	359	0.16
Lucky Peak	N. F. Boise	2	-14.50 14.85	108	-0.13

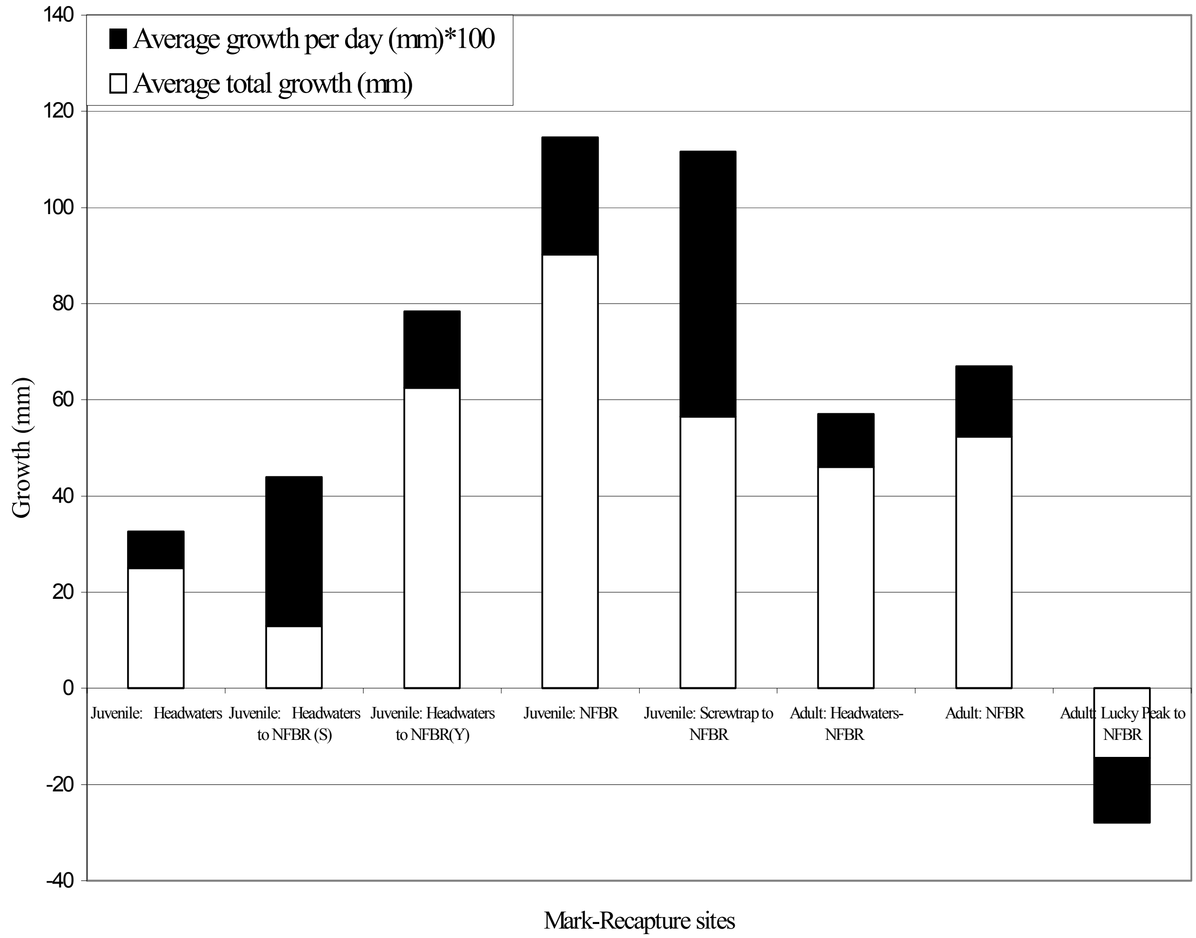


Figure 2. Growth for adult and juvenile size class groups at the various locations of capture (Y = one year between mark and recapture, S = summer season between mark and recapture times).

Results (Method of Capture)

Significant relationships were found for multiple habitat variables across the four regions in which sampling occured. Each method of fish capture imposed sampling at a different hydrologic scale and additionally had capture efficiencies limiting the kinds of analyses that could be conducted. Consequently all analyses are calculated at the method level and are reported at that level.

Headwater Streams: Spawning and Early Rearing Habitat

Numbers of Fish Captured

A total of 402 bull trout were captured in both years by electrofishing of which 282 were PIT tagged. Tributary-captured bull trout ranged from 30 mm to 420 mm TL (Figure 3). Dominant age classes were 0+, 1+ and 2+ size bull trout (Tables 3 and 4). Some adfluvial adults were captured in tributary streams in mid-August. Year 2000 had greater numbers of bull trout caught per site (but lower mean catchability) in the tributaries (Table 6). However due to equipment malfunctions which occurred in 2000 not all sites were sampled. Five of the Upper North Fork sub-watershed stream sites were not sampled in 2000. These streams represent the colder, small, high elevation sites with highest densities of bull trout (from 1999 work) (Appendix E: Table 1.E).

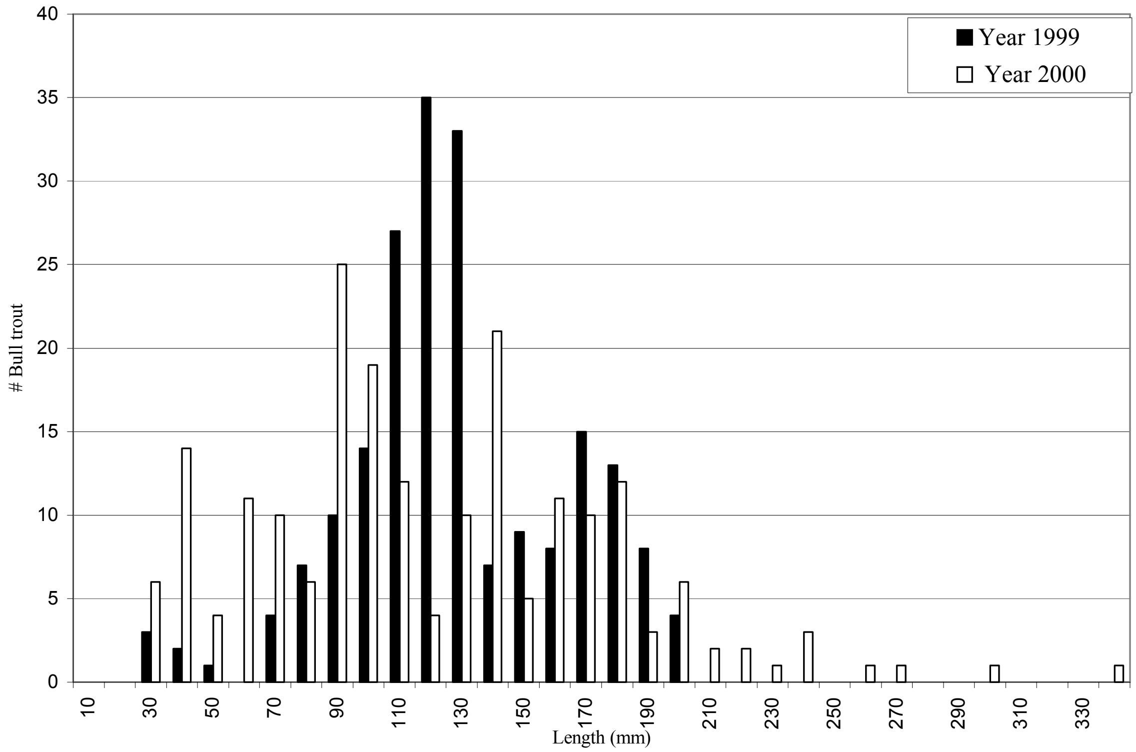


Figure 3. Length frequencies of bull trout collected from the headwater tributaries during the 1999 and 2000 surveys.

Age Classes and Growth

Three age classes were consistently found in tributary streams both years: 0+, 1+, and 2+ (Tables 3 and 4). Several large, most likely adfluvial adults were sampled in tributary streams in later August and are reflected in the length frequency charts (Figure 3). There were several between year differences from 1999 to 2000 in age class mean length and range (Tables 3 and 4). These differences possibly were related to the flow differences and increases in total catch by electrofishing for smaller age classes (Table 6). Additionally, the higher elevation sites could not be sampled in 2000. These sites had a large number of bull trout with mean TL of 110 mm in 1999. Losing these fish from the catch composition in 2000 could also account for the differences shown. The linear regression model for tributary bull trout age class had a significant positive relationship with increasing total lengths and is shown in Appendix D: Table 2.D (square root transformed data: Age = -3.73 + 0.47 sqrt (length) $r^2 = 0.69$, $p < 0.01$).

Population Parameters

Densities where bull trout were present in 1999 ranged from 0.12 to 32.10 bull / 100 m^2 with 34 of 54 sites sampled containing bull trout (Table 6, only sites sampled with bull trout in both years are shown for comparison). Two-pass densities where bull trout were present ranged from 0.22 to 14.50 bull trout / 100 m^2 in 2000, with 25 of 50 sites sampled containing bull trout.

Table 6. Headwater stream population estimates based on Seber – Le Cren equations as shown in Methods

Site Location		**1999 Estimates**					**2000 Estimates**				
Stream Name	Site rkm	2-pass Estimate (N)	2-pass Variance V(N)	Catch-ability (q)	Catch-ability Variance V(q)	Density (bull trout/ 100m²)	2-pass Estimate (N)	2-pass Variance V(N)	Catch-ability (q)	Catch-ability Variance V(q)	Density (bull trout/ 100m²)
Ballen-tyne	0	5	0	0	0.67	1.4	1	0	1	0	0.23
Ballen-tyne	0.78	22	14.19	0.64	0.04	3.78	8	24	0.5	0.19	1.83
Ballen-tyne	1.41	1	0	1	0	0.23	18	360	0.33	0.19	3.65
Ballen-tyne	3.28	28	127.79	0.46	0.06	6.9	15	3.72	0.73	0.03	4.56
Bear Cr.	6.25	5	0	0.67	0.15	1.59	3	0	1	0	0.98
Bear Cr.	6.41	7	0.4	0.83	0.03	2.71	1	0	1	0	0.41
Bear Cr.	7.5	1	0	1	0	0.26	5	2.25	0.67	0.15	1.6
Bear Cr.	8.44	9	180	0.33	0.37	2.76	1	0	1	0	0.42
Bear R.	18.75	1	0	1	0	0.41	1	0	1	0	0.37
Bear R.	7.81	1	0	1	0	0.18	1	0	1	0	0.28
Bear R.	14.84	3	0	1	0	0.67	61	12251.3	0.18	0.14	14.5
Big Silver	3.44	7	0.4	0.83	0.03	2.17	14	6.75	0.67	0.05	4.89
Crooked R.	33.75	2	0	0	2	0.36	10	2.82	0.71	0.05	2.34
Crooked R.	34.38	3	0	1	0	0.59	61	7040	0	0.2	14.5
Crooked R.	37.5	1	0	1	0	0.29	9	0.24	0.88	0.02	2.56
Cub Cr.	0	1	0	1	0	0.26	5	0.99	0.75	0.08	1.63
Johnson	7.81	1	0	1	0	0.13	5	0	0.67	0.15	0.46
Johnson	10.94	1	0	1	0	0.25	4	12	0.5	0.38	0.74
Lodge-pole	0.63	2	0	1	0	0.54	25	34.45	0.57	0.04	8.42
Lodge-pole	0.78	12	1.48	0.78	0.03	4.01	19	7.01	0.69	0.03	5.38
Mean	**n/a**	**5.65**	**16.213**	**0.78**	**0.17**	**1.47**	**13.35**	**987.28**	**0.69**	**0.08**	**3.49**

Response to Environmental Factors

Electrofishing sites were divided into two groups: those with bull trout (present) or those without bull trout (absent). Each site had 29 individual measurements of habitat taken or calculated from the data taken (Appendix B: Table 1.B). To increase the observation to variable ratio, I used a Pearson product-moment analysis to identify highly correlated variables. I selected the variables that were reported to be important indicators of presence or absence of bull trout (Pratt 1992, Rieman and McIntyre 1993, Fraley and Shepherd 1989) from the highly correlated (correlation coefficient > 0.75) variables. Finally, stepwise linear discriminant function was run to identify variables that best predicted presence or absence of bull trout. In 1999, temperature, fast water length and width, undercut banks, and pool width were the five best independent variables related to presence or absence, with error rates of 12.5% (presence) and 25% (absence). The analysis for 2000 data showed pool crest depth, date, pool width, fines, and aggregate large wood debris to be best independent variables with error rates of 19.04% (presence) and 21.74% (absence).

Differences in independent variables between years most likely reflect the low variation expressed in the 2000 data. Due to damages incurred in sampling equipment in 2000, the high density, high elevation sites could not be sampled and consequently may contribute to the differences shown in the independent variables of the model between 1999 and 2000. The discriminant function model results are shown in Appendix D: Table 1.D.

Best independent variables from the models were: stream width, percent available cover, overhanging vegetation cover, date, and temperature ($p < 0.01$) in 1999. When highly correlated variables were removed, there was a significant relationship between increasing densities with the combination of the decreasing variables: total cover, temperature (log transformed), and elevation (density = -0.31 x elevation –323.75 X log (temperature) – 0.08 x total cover + 1365.76, adjusted $r^2 = 0.42$, $p = 0.0004$). Year 2000 had several of the high density, high elevation sites removed due to sampling problems, so significant models were not found. The 1999 regression model is shown in Appendix D: Table 7.D).

Trapping Efficiencies

I used the Seber-Le Cren catchability equation to estimate the efficiencies of the electrofishing surveys. The mean catchability between years shows that catchability actually decreased between which incorporates substantial error. For example, if the first pass has fish and second none, the catchability will be one (reflecting zero as a denominator error plus one). In this case catchability reflects an error as a numerical value which is calculated in the mean catchability as one rather than zero and increases the mean. What actually occurred is that both the total catch increased from 1999 to 2000, and the catchability actually reflects error in the equation for most sites (one or more fish captured in the first pass and none in the second). Actual efficiencies could only be calculated at sites that have depleted numbers of fish from first to second pass and with fish captured in the second pass. When this was considered, the catchability equation was not a valid error estimator for many of the sites. Therefore, conclusions must be drawn from total catch and total catch variance between years. Most likely the increase between total catch for 1999 and total catch for 2000 is associated with increased electrofishing efficiency due to lower water levels between years (Discussion).

Crooked River: Migration Corridor

Numbers of Fish Captured

A total of 57 bull trout were captured, and 56 were tagged at the screw trap during nine weeks of operation from May 31, 2000 to August 1, 2000. Captured bull trout were 110 mm to 240 mm total length and 35 g to 140 g in weight in 2000 (Figure 4).

Age Classes and Growth

Only one bull trout was captured that represented age class 1+, all others were within the length range of age classes 2+ or 3+. A small sample of bull trout (4) was aged to 4+ (N = 3) and 5+ (N = 1) age classes, although the lengths of these bull trout would assign them to the length frequency range for 3+ juveniles (Table 3) based on the combined age by length regression model.

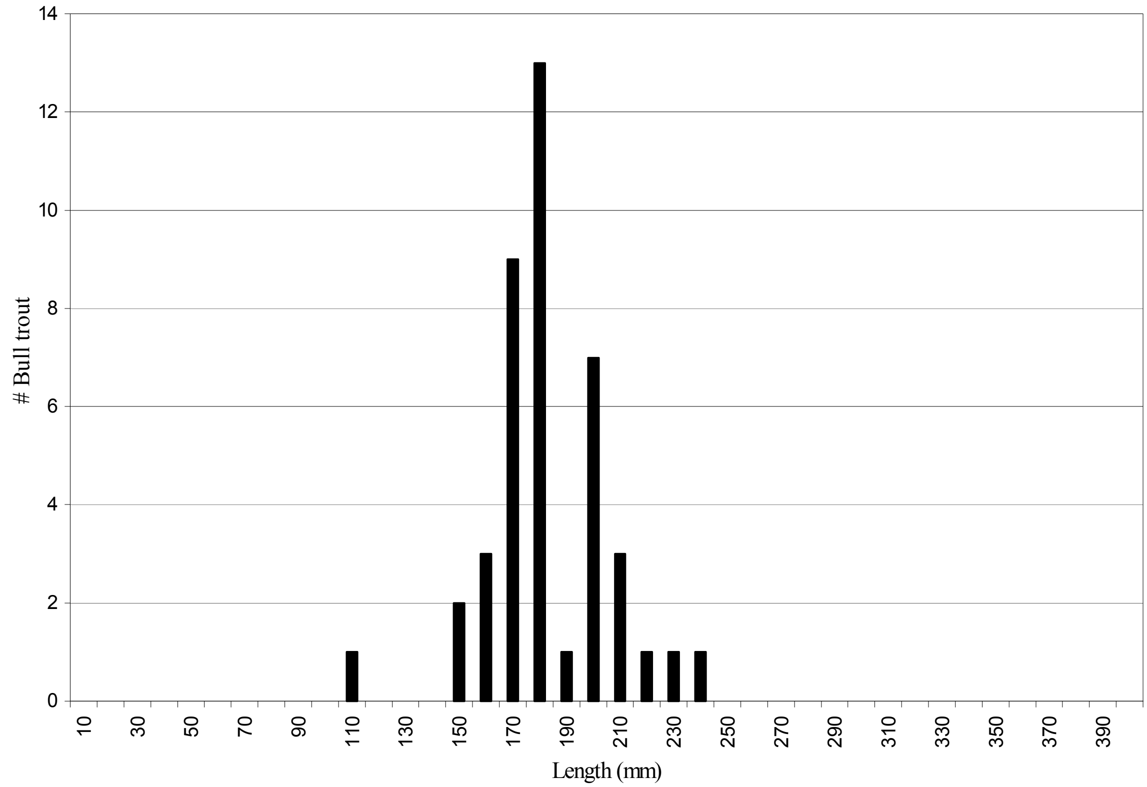


Figure 4. Length frequencies of bull trout collected from the Crooked River trap site during 2000.

Population Parameters: Recruitment

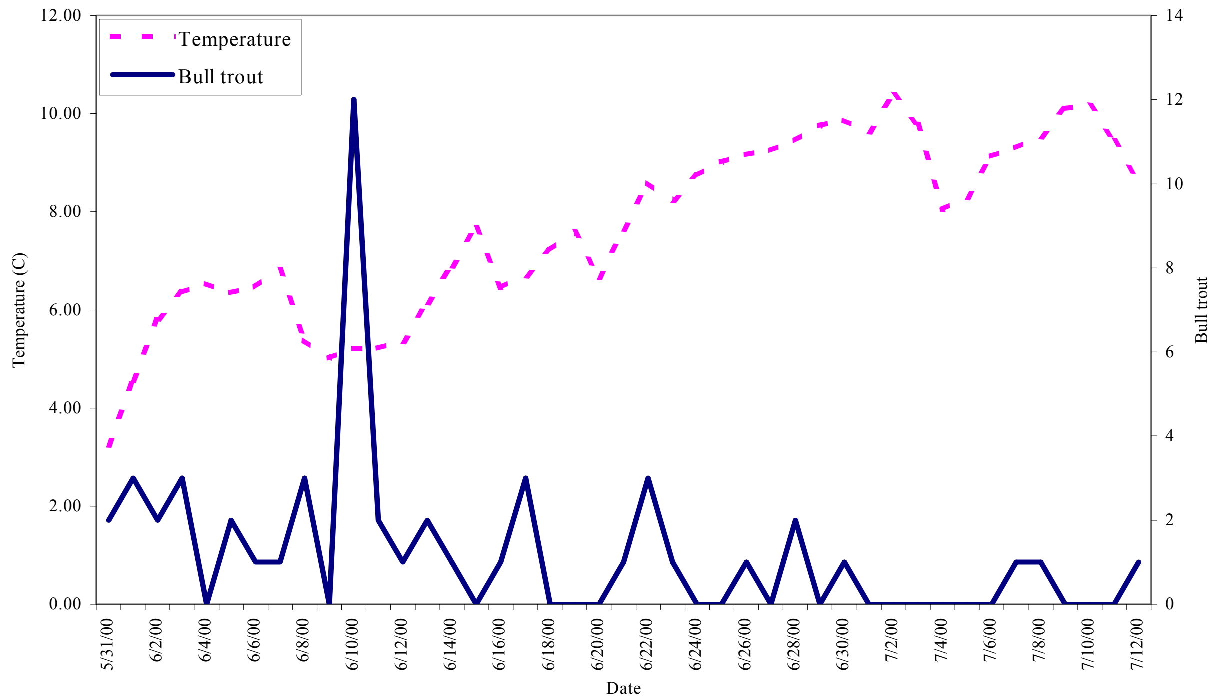
Table 7 lists weekly capture efficiencies calculated for the Crooked River screw trap. The average weekly capture efficiency was calculated to be 7.80% (s = 0.089). Total recruitment was estimated to be 777 bull trout (528 - 21574) bull trout.

Responses to Environmental Variables

Figure 5 shows the raw data and the detrended residuals for the number of bull trout captured per day and mean daily temperature at Crooked River km 21.5. Catch per day and temperature at the trap was highly influenced by date. No significant relationship was found for catches per day with temperature and flow at the Crooked River trap for detrended models (Appendix D: Table 8.D and 9.D).

Table 7. Screw trap recruitment by week and total estimated recruitment for the nine weeks of operation in study year 2000.

Week	Number of bull trout marked	Number of bull trout recaptured	Calculated efficiency	Mean Efficiency	Estimated recruitment	Lower bound of recruitment	Upper bound of recruitment
1	13	2	0.15	N/A	73.00	122.64	2027.78
2	21	1	0.05	N/A	420.00	198.11	11666.67
3	5	0	0	0.07	70.42	47.17	1956.18
4	5	0	0	0.07	70.42	47.17	1956.18
5	3	0	0	0.07	42.25	28.30	1173.71
6	2	0	0	0.07	28.17	18.87	782.47
7	3	0	0	0.07	42.25	28.30	1173.71
8	2	1	0.50	n/a	2.00	18.87	55.56
9	2	0	0	0.071	28.17	18.87	782.47
Total 9-weeks and mean efficiency	**56**	**4**	**0.07**	**0.04**	**776.69**	**528.30**	**21574.73**



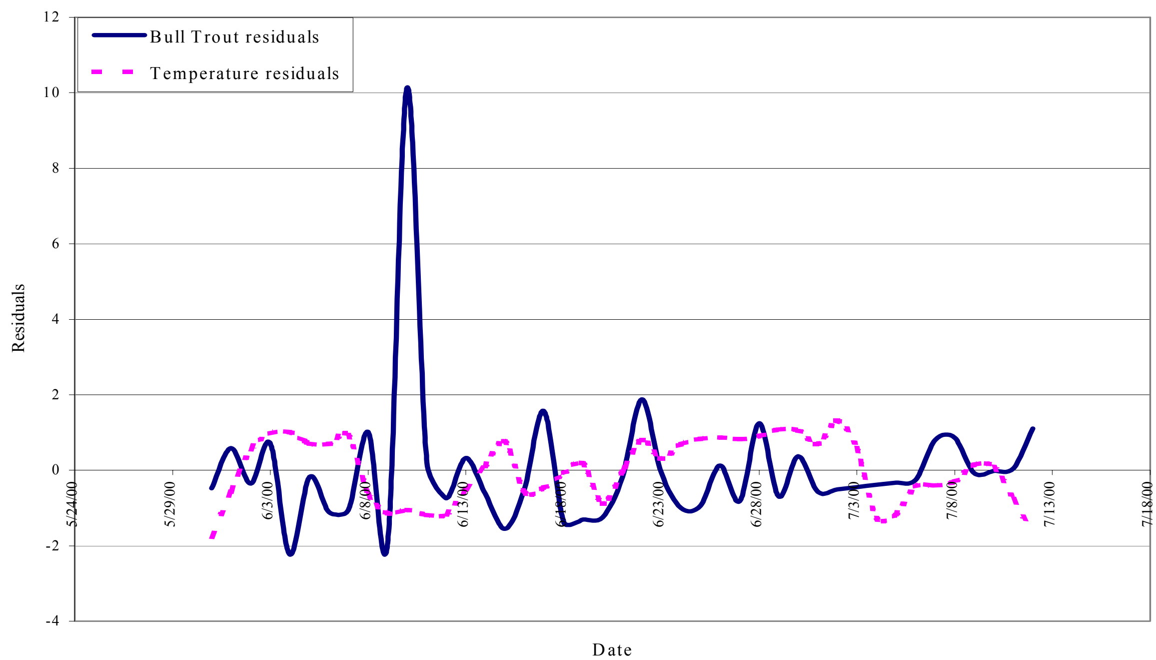


Figure 5. Raw data and residuals for bull trout captured per day and daily mean temperature from Cooked River km 21.5.

Trapping Efficiencies

I experienced very low recapture rates at the screw trap and consequently low capture efficiencies (Table 7). This could be due to a number of factors including a learned response from the fish. Finally, since the trap relies on higher flows for rotation of the cone, declining flows over time may contribute to the reduced ability of the trap to retain fish in the trap box (Figure 5, see Discussion).

North Fork Boise River: Migration Corridor

Number of Fish Captured

The North Fork weir was operated 24 hours per day from August 28, 1999 to October 23, 1999 and August 26, 2000 to October 21, 2000. A total of 698 bull trout were captured and 678 tagged. Twenty bull trout were not tagged due to size, condition (visible infirmity or injury), or equipment malfunction. Year 1999 bull trout captures consisted of 112 adults and 152 juveniles while year 2000 captures were composed of 148 adults and 286 juveniles (where bull trout < 300 mm are considered juvenile and > 300 mm adults based on Flatter 2000). Bull trout captured in 1999 ranged from 180 mm to 695 mm in total length and 60 g to 2800 g in weight. Bull trout captured in 2000 ranged from 160 mm to 715 mm total length and 56 g to 2785 g in weight in 2000 (Figure 6).

Four juvenile size bull trout became impinged by their gill covers between the weir pickets and died in 1999, this number increased to seven in 2000. All retained mortalities were examined for gender and sexual maturity and otoliths and scales were removed for later aging.

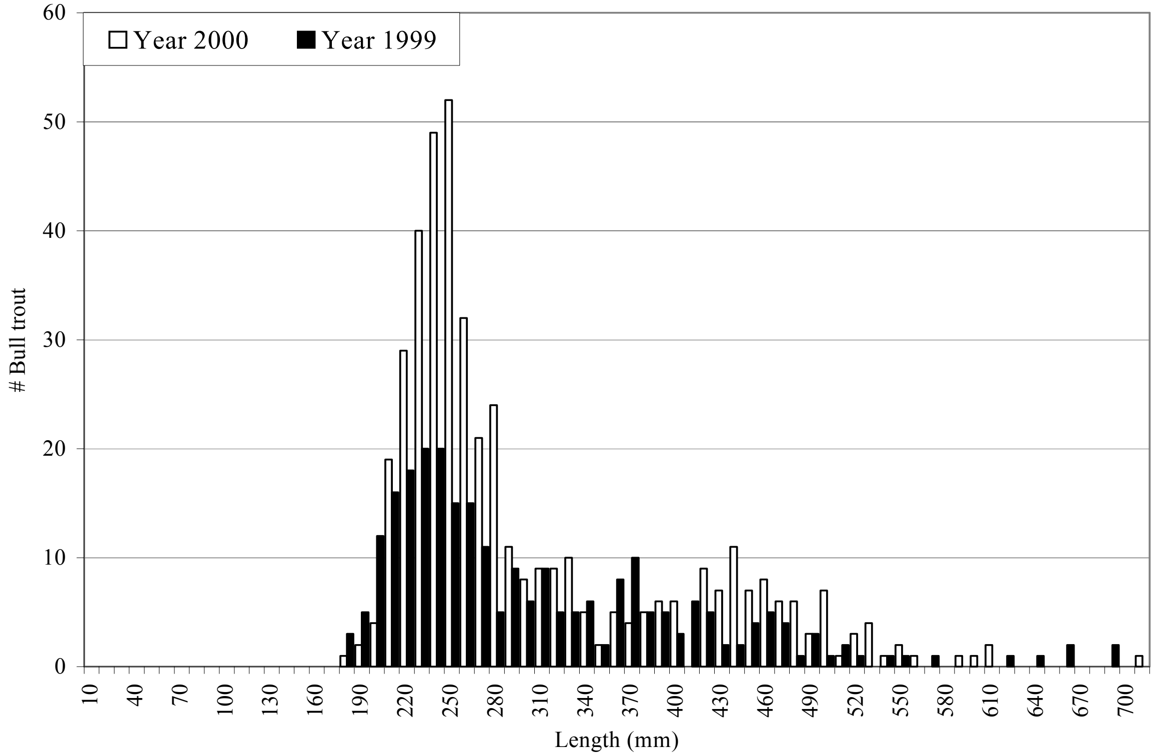


Figure 6. Length frequency distribution of bull trout collected in the North Fork Boise River weir trap in 1999 and 2000.

Age Classes and Growth

Adult mean age estimated from the weir captured bull trout was 6+ and 7+ for 1999 and 2000, respectively. Linear regressions showed a significant positive relationship for increasing age class with increasing total length. Age and length data were used to create models for weir and combined method capture data (Appendix D: Tables 4.D and 6.D). The combined model is reflected in the mean lengths and length ranges (Table 3), comparisons are made with other values reported for the Northwest and Canada (Table 2). Actual data mean lengths and ranges are shown in Table 4 and Appendix D: Figure 1.D.

Bull trout were separated into two groups to estimate age class contribution: juveniles (total length < 300 mm) and adults (total length > 300 mm). Over half of the bull trout captured at the weir in both 1999 and 2000 were of the juvenile size class (55.0% in 1999 and 65.0% in 2000). Juvenile bull trout were aged to three year-classes, 2+, 3+, and 4+. Juvenile bull trout were dominated by age class 3+ (57.9%) and 4+ (55.5%) in 1999 and 2000 respectively. Trends in the size of each year class appear to continue from 1999 to 2000, with large single year cohort classes aging one year between years. The trends are exemplified by age class 3+ comprising the majority of the juvenile bull trout in 1999 and age 4+ comprising the majority of juveniles in 2000. Large single year class trends are also shown in adult bull trout migrants for age class 6+ in 1999 (37.7%) and 7+ (33.6%) in 2000.

A total of 155 scale samples were analyzed in 1999 and 577 scale samples were analyzed and read in 2000 by the same readers. Average percent error (APE) for 1999 between readings ranged from 16.6% to 17.8% and between readers 31.2% to 36.8%

(where N=155). Otolith validation between structure reading APE was 4.6% for adult fish (one reader, N = 24). Average percent error between otoliths from mortalities was relatively low for juvenile (12.5% for juveniles, N = 8). However, sample size for juveniles was low and may account for the difference between error for adults and juveniles. The 1999 regression model equation r^2 value was 0.79 on square root transformed length data. APE for 2000 between readings ranged from 2.71 to 3.67 percent and between readers was 14.7% to 23.1% (where N = 577). The 2000 regression model equation r^2 value is 0.74 on square root transformed data. The combined model for 1999 and 2000 was used for all age data. Combined model adjusted r^2 value is 0.78 for square root length transformed data (Age = -3.02 + 0.43 X sqrt (length)).

Annual Patterns of Growth

Three juvenile sized bull trout were marked at the weir in 1999 and recaptured at the weir in 2000 growing an average of 90.30 mm in total length (s = 22.19). Sixteen adult bull trout were marked at the weir in 1999 and recaptured in 2000 growing an average of 52.37 mm in total length (s = 15.63). Two juvenile bull trout were marked in headwater tributaries in 1999 and recaptured at the weir in 2000 growing 62.60 mm in total length (s = 36.00). One adult bull trout was marked in the tributaries in 1999 and recaptured at the weir in 2000, growing 46.00 mm in one year. All growth for marked and recaptured bull trout is shown in Table 5 and Figure 2.

Seasonal Patterns of Growth

One juvenile bull trout was marked in the tributaries in July 2000 and recaptured at the weir in September 2000, growing 13 mm. Three juvenile bull trout were marked at the screw trap in 2000 and recaptured at the weir in 2000 growing 53 mm in total length (s = 22.19). Two adult bull trout were marked in Lucky Peak reservoir prior to spawning, released into Arrowrock reservoir and recaptured at the weir in 2000. These bull trout lost an average of 897 g and 14.5 mm total length (s (TL) = 14.89).

Daily growth for bull trout recaptures is shown on Table 5 and Figure 2. Two bull trout that were tagged and released during the trap and transport project were recaptured at the weir. These fish had 101 and 105 days pass between mark and recapture, and were recaptured at North Fork River km 14.8 that is 55 km from the release site. They were captured and released from the downstream trap. Each had lost some length and substantial weight: 0.04 mm per day and 2.99 grams per day and 0.22 mm per day and 12.97 grams per day for the fish with 101 days and 105 days between recapture respectively. These fish were aged 8+ (525 mm length) and 9+ (620 mm length) from the 2000 combined model, with the largest and oldest fish losing the most length and weight overall and per day. Three bull trout that were recaptured at the screw trap were recaptured later in the season, either at the North Fork weir, or at the screw trap. The two weir recaptured bull trout gained an average of 56.6 mm in length (s = 8.89) with daily average growth equal to 0.55 mm. The bull trout that was recaptured at the trap two months later grew 46 mm, with average growth per day of 0.92 mm.

Population Parameters: Mark Recapture Estimate

In year 1999, 110 bull trout (> 300 mm TL) were tagged at the weir with 16 of these bull trout being recaptured in 2000. The North Fork migratory adult bull trout population estimate was 969 (s = 228) bull trout > 300 mm. The range of adult population estimates that include adjusted recapture values to consider immigration and tag loss was 385 to 969 bull trout (assuming mortality between years is the same). Table 8 shows the range of estimated populations with the application of varying treatments. As estimates of immigration (young bull trout becoming sexually mature) increased, the overall population estimate decreased, but this effect is amplified when tag loss were included. An estimate of the juvenile bull trout population was not made due to characteristics associated with the life history of the fish and capture method bias (Discussion).

Table 8. North Fork Boise River weir population estimate based on mark-recapture equations from Shaeffer et al. (1996). Estimates included varying levels of treatments: tag loss, and natural maturation or immigration.

Method	**# Fish marked in 1999**	**# Fish recaptured in 2000**	**# Marked 2000**	**Population Estimate (1999 post-spawning >300 mm TL)**	**Standard Deviation**
No Treatment	110.00	16.00	141.00	969.38	228.18
20% Immigration	110.00	16.00	113.00	776.88	179.94
40% Immigration	110.00	16.00	86.00	591.25	133.36
60% Immigration	110.00	16.00	56.00	385.00	81.35
Tag Loss	110.00	18.88	141.00	821.50	175.95
Both treatments (40% Immigration)	110.00	18.88	86.00	501.06	101.87

Response to Environmental Variables

The weir trap boxes were checked three to four times daily to monitor movement patterns at they relate to light conditions on a daily basis as well as movement related to seasonal and annual temperature, flow, and precipitation levels. Results from the weir trap are reported for daily, seasonal, and annual patterns.

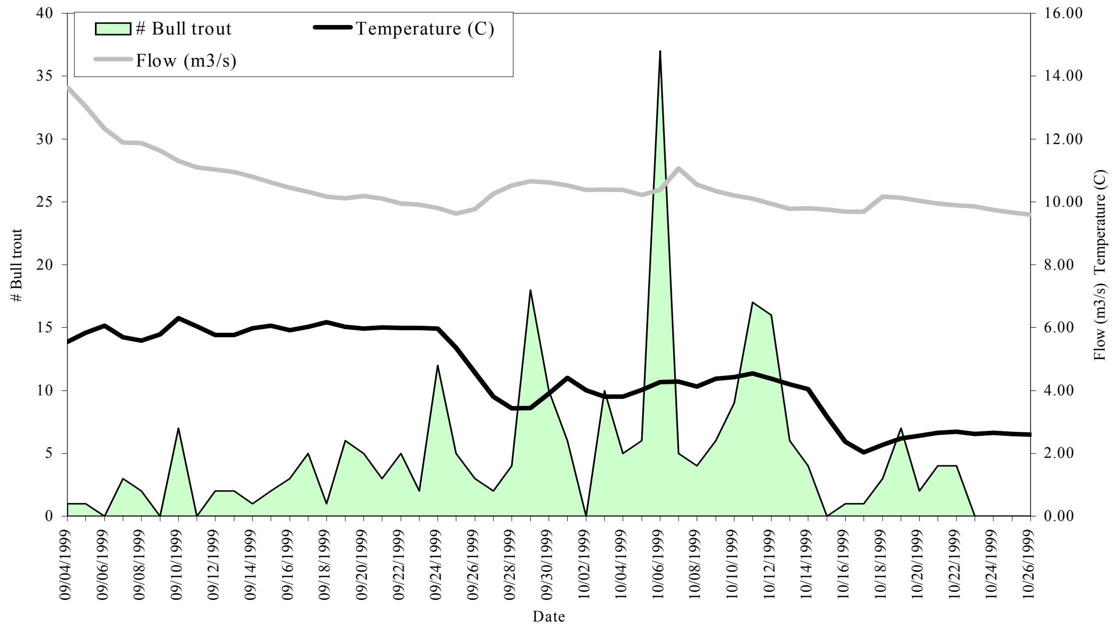
Daily Movement at the North Fork Trap

Bull trout migrated primarily at night: 41% of captured Bull trout were captured between 17:00 and 22:00 and 53.4% were captured from 24:00 to 7:00. The remaining 6.0% were captured between 7:00 and 17:00 (Appendix F: Table 1.F). All of the bull trout that were captured in year 2000 were captured in the downstream trap indicating that the fish were moving downstream. Year 1999 had a small percentage of bull trout captured in the upstream trap (4.5% as shown in Appendix F: Table 2.F). Adult bull trout had a tendency to be captured in pairs. However, smaller bull trout often moved in large groups and were noted to move with bull trout of similar size.

Seasonal Movement at the North Fork Trap

Only year 2000 weir capture data was used for modeling because 1999 had no major precipitation events during the trap operation, and consequently a low variation in flow and temperature with one major temperature change and one major bull trout movement. Figure 7 shows the raw data of juvenile and adult bull trout captured daily at the traps, mean daily temperature, and flow during 1999 and 2000. Figure 8 shows the detrended residuals for adult and juvenile bull trout from year 2000 with flow and temperature. The regression model showed a significant relationship for juvenile bull trout catches per day with temperature and flow. Juvenile catches increased with declining mean daily temperature and declining mean daily flow (Catch per day = - 0.74 (temperature) - 0.75 (flow) + 4.2-06, adjusted $r^2 = 0.51$, $p < 0.0001$). There was no significant relationship shown for adult bull trout catches per day with flow and temperature. Regression models for weir captures as related to temperature and flow are shown in Appendix D: Tables 10 – 13.D).

Year 1999



Year 2000

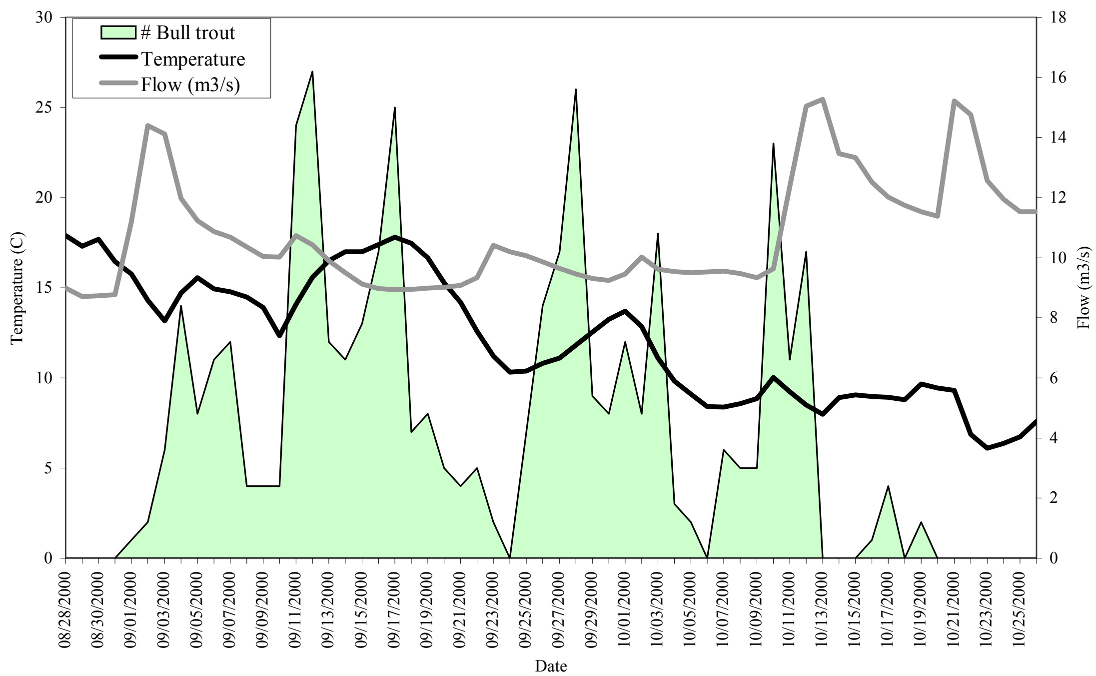
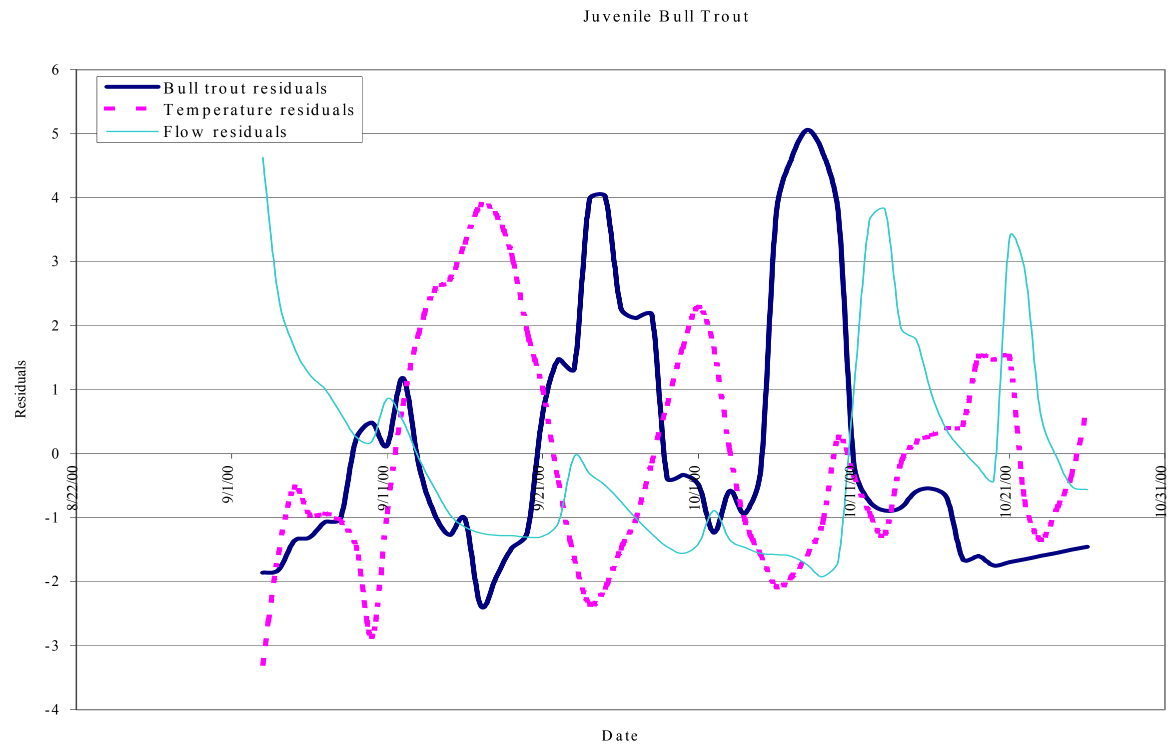


Figure 7. Number of bull trout captured per day at the weir trap with mean daily flow and temperature.



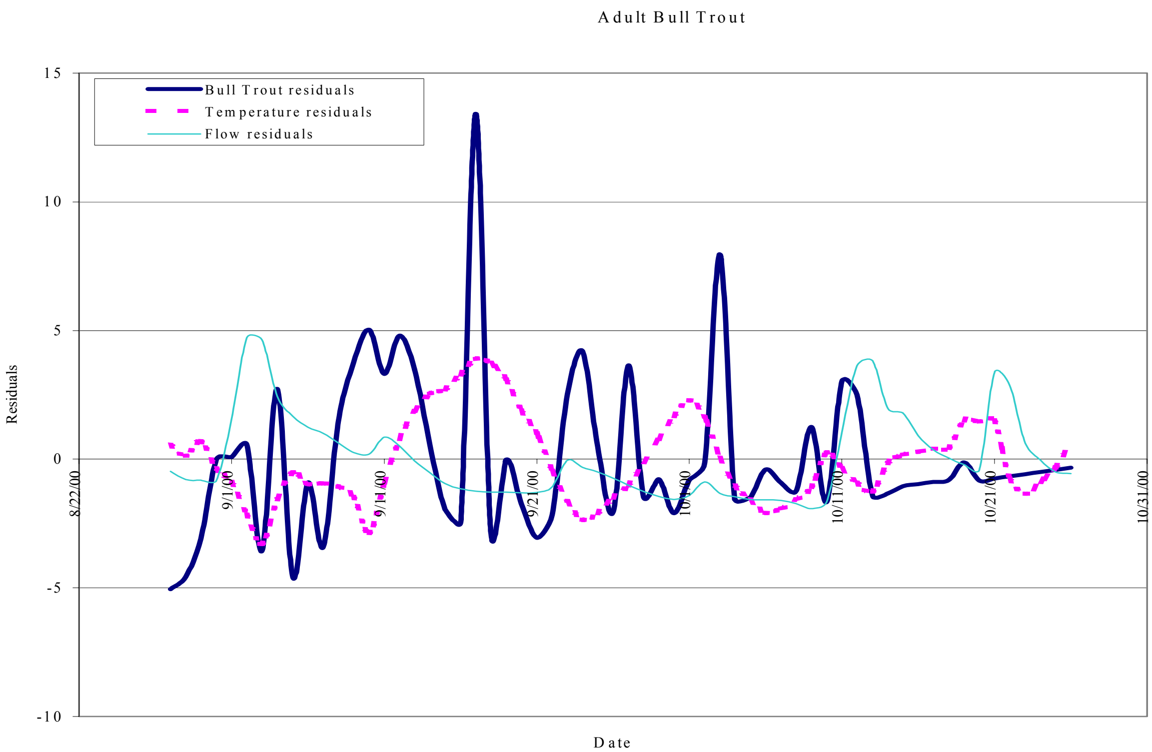


Figure 8. Year 2000 juvenile and adult catch per day, flow, and temperature residuals from date regressions.

Relationships to Annual Survival: North Fork Trap

A possible relationship was observed between weak year classes of bull trout and reduced annual precipitation and flow (Figure 9). Weir captures were low for fish in age classes 0 + - 2 + and 9 + - 11 + in both years, and a small sample size of years with representative data is shown. For example, the year class of 1993 appeared to be strong while year class 1994 mave have been weak. Relatively high and unusually low flow and precipitation were observed during each of those years respectively. The apparent relationship in later years (1997, 1998) is confounded by differences in capture efficiency for juvenile and adult fish and by the influence of mortality as fish age. Without removing the effect of natural mortality, the apparent trend in recruitment and flow across all years will confound the true pattern. Due to the magnitude of error associated with the assignment of year classes (from a regression) and assumptions of constant mortality for each year class, the data was not modeled. Further work is important to explore the apparent relationship.

Trapping Efficiencies

Thirteen bull trout were released above the trap over three weeks in 1999 to investigate the efficiency of recapture. Six of these bull trout were recaptured. All six bull trout were the largest fish from the initial sample. Additionally, two bull trout that were tagged and released downstream of the weir were recaptured in the downstream trap indicating they had passed through the pickets to go upstream and then were recaptured in the downstream trap box. These fish were both less than 300 mm TL. Finally, four juvenile size bull trout became impinged by their gill covers between the weir pickets and died in 1999, this number increased to seven in 2000 (2.7% and 2.4% of total juvenile catches respectively). The weir trap had very low rates of collection for bull trout < 200 mm in length and recaptured some bull trout < 300 mm TL that had moved through the pickets, which indicates that the trap is size selective for larger bull trout. Additionally, the trap was operated for a limited time frame and was washed out by discharges that exceeded 7.08 m^3/s when a three to five day precipitation event occurred.

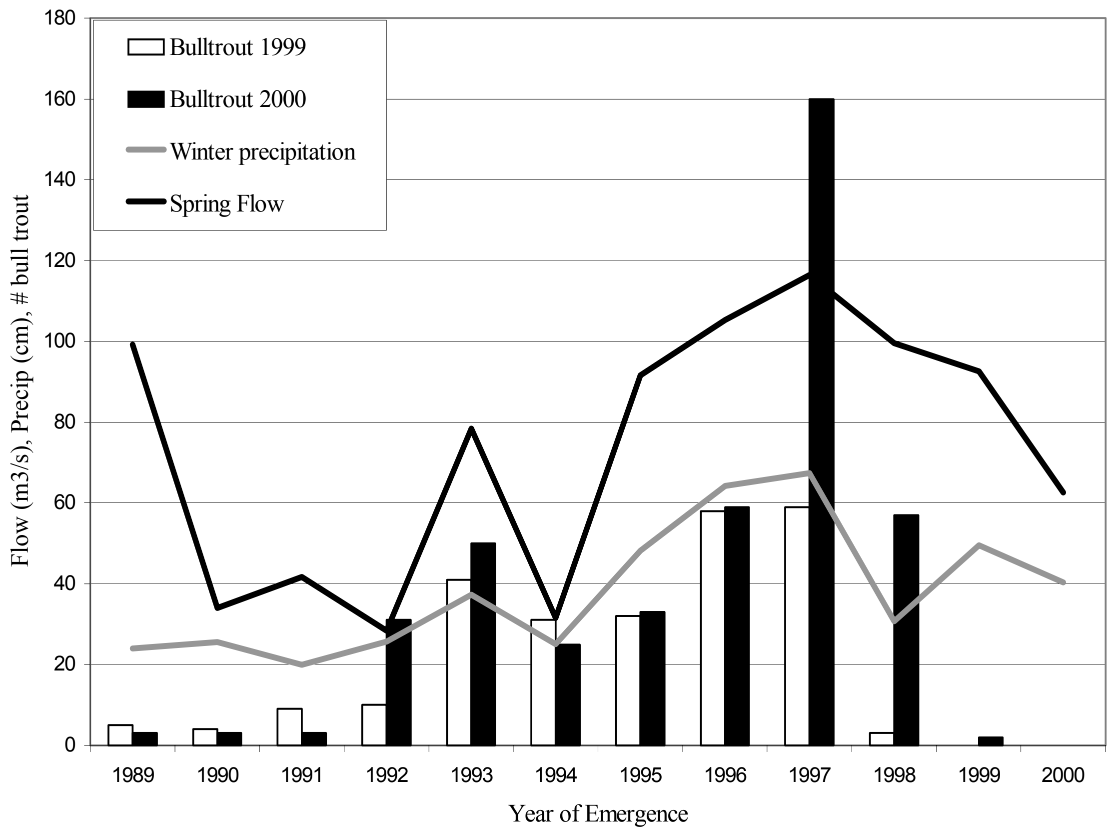


Figure 9. Number of bull trout collected at the North Fork Boise River weir trap from back-estimated emergence years. Mean Spring flow (March-June) and accumulated winter precipitation (November-April) are shown for each year.

Lucky Peak Reservoir: overwintering habitat

Number of Fish Captured

A total of 26 bull trout were captured, with 23 being tagged during the reservoir trap and transport project. Twenty-four of these bull trout were transported to Arrowrock reservoir, processed and released. Two bull trout were transported to the Morrison Knudson Nature Center for a public education project as requested by Idaho Department of Fish and Game. Captured bull trout ranged from 255 mm to 620 mm in length and 450 g to 3384 g in weight (Figure 10).

Age Classes and Growth

Lucky Peak bull trout represented five age classes, but were composed primarily of age class 7+ (52.0%) with age class 8+ being secondary (26.0%). Three bull trout were aged to 6+ (13.0%) one bull trout was age class 4+, and one was 9+ (Table 3). Scale linear regression models were not significant with such a small sample size and only two age classes represented strongly (Length data is square root transformed, Age = 1.05 +0.5 X sqrt (length), N = 18, $r^2 = 0.09$. $p = 0.12$) (Appendix D: Table 5.D).

Population Parameters: Catch Per Unit Effort (CPUE)

Table 9 shows daily and weekly catch per unit effort for bull trout and combined species. Weekly CPUE ranged from 1.54 to 5.67 fish per hour for all species and 0.03 to 0.24 bull trout per hour. Daily CPUE ranged from 1.30 to 8.87 fish per net hour for all fish and 0.0 to 0.45 bull trout per net hour. The average CPUE for the project was 0.09 bull trout per net hour (SE = 0.41), The trap and transport effort captured 1086 total fish including bull trout in 325.72 hours of netting.

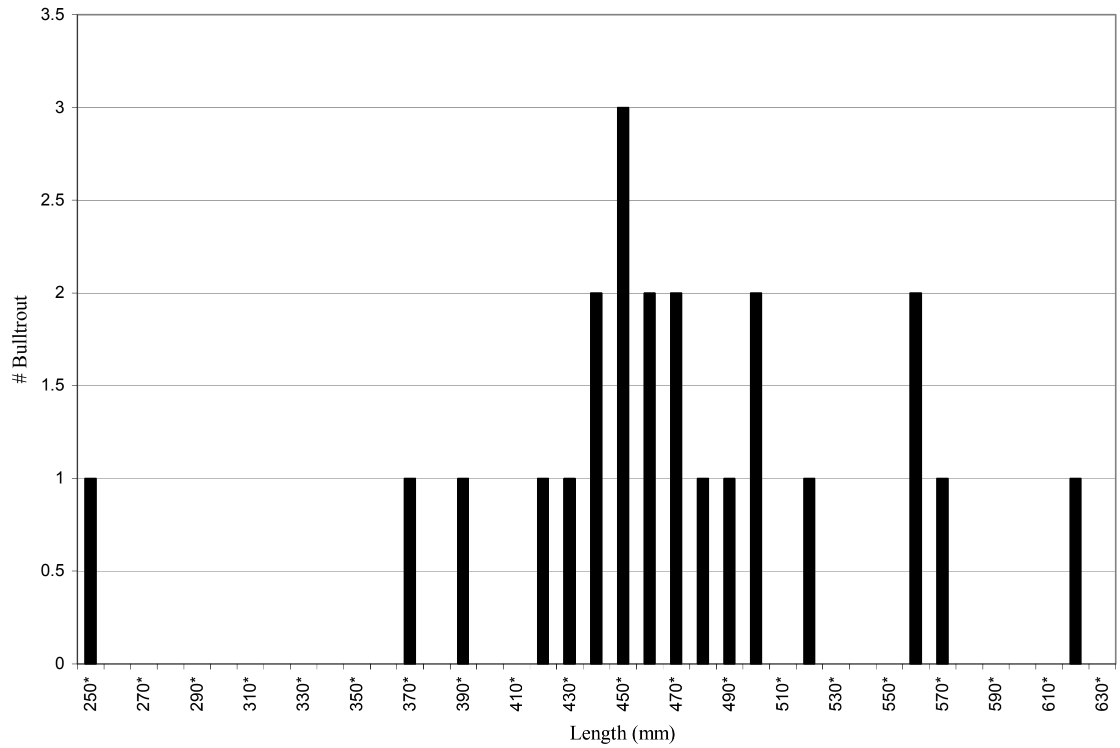


Figure 10. Length frequency distribution of reservoir captured bull trout in 2000.

Table 9. Weekly Catch per Unit effort (CPUE) for all fish species combined and bull trout from the reservoir. Lucky Peak reservoir elevation and Arrowrock discharge are also shown.

Week	**Total Fish CPUE**	**Bull Trout CPUE**	**Lucky Peak Elevation (msl)**	**ARK Discharge (m^3/s)**
1	1.86	0.03	927.39	166.47
2	2.93	0.04	927.56	151.93
3	4.69	0.04	927.29	139.50
4	5.47	0.06	927.96	120.25
5	5.67	0.12	928.41	131.07
6	3.27	0.05	928.78	136.79
7	1.86	0.24	931.12	136.36
8	1.76	0.07	931.08	122.48
9	1.54	0.05	931.19	140.07

Response to Environmental Variables

Figure 11 shows catch per unit effort as related to Lucky Peak reservoir elevation and inflow. There was a significant positive relationship shown for total fish caught per day (all species) with increases in Lucky Peak reservoir elevation and decreases in Arrowrock discharge (total fish / day = -2.90 X Lucky Peak elevation - 0.02 X Arrowrock discharge + 8968.3, $r^2 = 0.35$, $p = 0.03$, Appendix D: Table 14.D).. Total fish daily CPUE also showed this relationship, however slightly stronger ($r^2 = 0.44$, $p < 0.01$). Bull trout daily catch was predicted by increasing date, total fish captures per day and Lucky Peak elevation (bull trout per day = 0.03 X total fish per day + 0.08 X date + 0.41 X Lucky Peak elevation + 1713.73, $r^2 = 0.41$, $p < 0.01$). Bull trout CPUE also showed a weak positive relationship with increasing Lucky Peak elevation ($r^2 = 0.11$, $p = 0.07$) Dates were noted to be highly correlated to reservoir elevation, especially Lucky Peak elevation (Pearson Correlation Coefficient = 0.93, $p < 0.01$). Reservoir temperatures were unavailable for either reservoir, so were not included in the analysis. The highest catch was during the four-day period when Lucky Peak was held at elevation 930.85 m where crews captured 34% of total bull trout (see Table 9 and Figure 11).

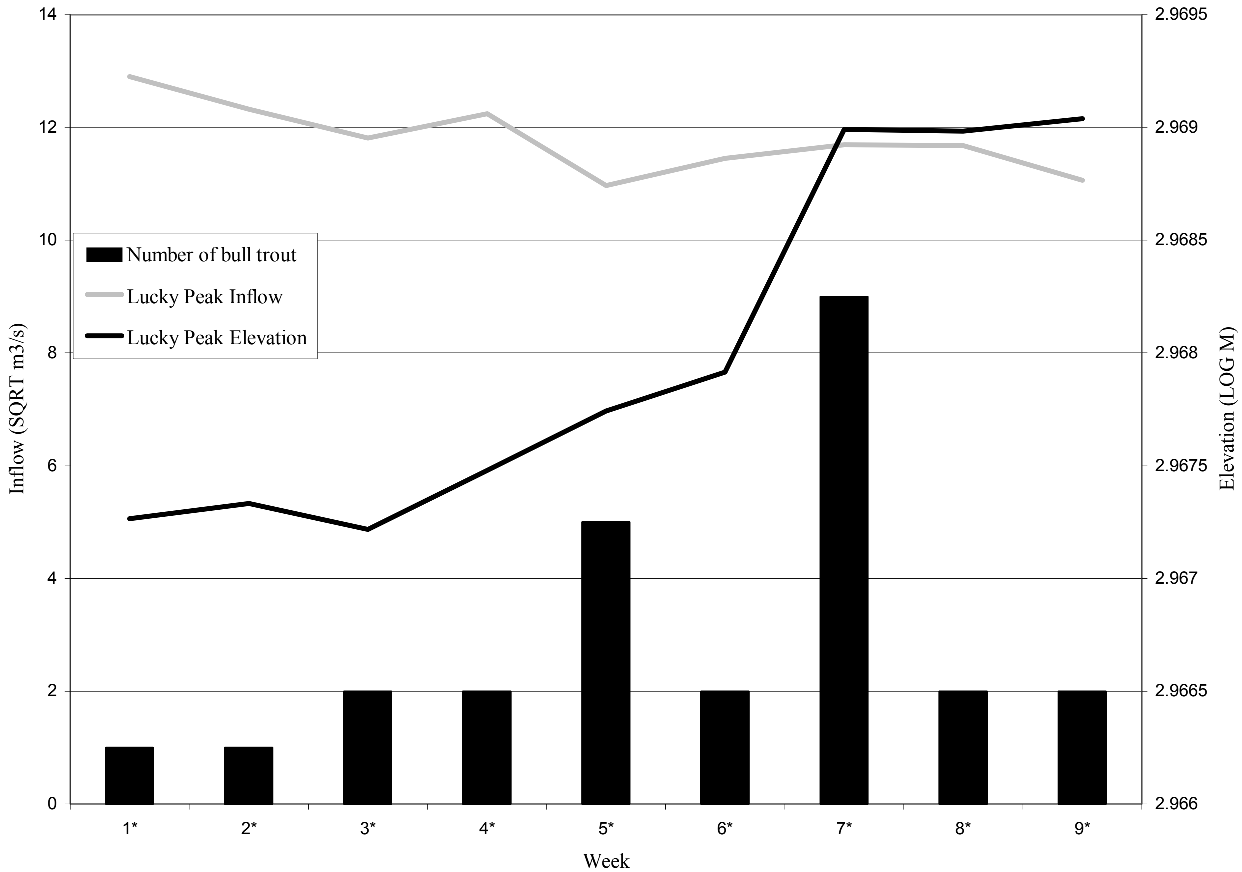


Figure 11. Bull trout weekly total catch per unit effort with weekly mean reservoir elevation and inflow for Lucky Peak Reservoir. Due to low weekly bull trout catch rates (1-9 bull trout per week), elevation and inflow are transformed to fit graph axes for clarity in illustration.

Ranges of Catch per Unit Effort

Experimental monofilament gill nets were used as recommended by Idaho Department of Fish and Game personnel for capture in Lucky Peak reservoir. Sampling effort was conducted randomly across Lucky Peak reservoir, and found that most of our bull trout captures were in close proximity to Arrowrock Dam in late May and early June (76% from May 16 to June 15, 34% from May 30 to June 1). CPUE was highest when Lucky Peak Reservoir elevation was highest during late May and early June.

Discussion

Organisms in highly variable environments will often disperse or migrate to avoid inhospitable conditions (Fretwell 1972). Migratory behavior is thought to be the result of taking the risk of increased predation and energy expenditures associated with movement over remaining in poor habitat condition (low prey availability, cover, high densities of same species) (Fretwell 1972). Ectotherms such as salmonid fishes reap the benefit of increased size (consequently increased fecundity) with increased prey base, making the benefit of migration even greater (Healy 1994). Additionally, Rieman and McIntyre (1993) discuss the importance of diverse life histories (as components of a population) to the stability and persistence of those populations because variable environments can cause selection pressures to change rapidly. Rieman et al. (1997) emphasize the importance of multiple life history forms and the influence that migratory forms of fish have to restore apparently extirpated populations if suitable habitat exists. The North Fork Boise River bull trout size and age distribution fit a migratory population structure. My work found size segregation and presence of age classes across a broad range of habitats that fit life history discussions of migratory fish population structure. Resident and fluvial bull trout could reside in the larger lotic waters, but could not be and were not discerned.

Size, Age Classes, Timing of Movement

The distribution data presented in this study supports distribution data of Smith-Dorrien Creek adfluvial populations of bull trout near Calgary, Canada. In this river system, Stelfox (1997) found length ranges of 32 - 308 mm in bull trout with most captured bull trout being 61 - 100 mm in size. In my electrofishing work in the small spawning and rearing streams, I found greater densities of juvenile bull trout in the upper reaches of the creeks, with ranges of 30 - 240 mm: most being 80 - 130 mm in size. Stelfox did not report age for these fish, but presumed them to be age class 1+. I found bull trout densities that were slightly higher than those found by Goetz (1991) for the Metolius system; and Adams and Bjornn (1997) in the Weiser drainage, Idaho. However, the difference in findings may be due to different methods used for the estimates (electrofishing versus snorkeling).

Ratliff et al. (1996) suggests that juvenile bull trout migrate directly into the reservoir in the spring at age classes 2+ to 3+. My data suggests that there may be two major migrations in a large tributary or river. One migration in the spring (as evidenced by the screw trap data) and another in the fall (as evidenced by weir data). Bull trout recapture data suggests that juvenile size bull trout, which migrate in the spring, may not move directly into the reservoir. These fish may spend the summer in small tributaries, then move in autumn to large river and reservoir systems. Juvenile fish captured in the weir and screw trap were primarily age class 3+. This finding supports the hypothesis that age 3+ is the dominant age that juveniles will migrate (McPhail and Murry 1979, Ratliff et al. 1996, Stelfox 1997). Further, the weir trap data support the notion that the downstream movement of bull trout occurred during the fall, and at night (Stelfox 1997, Muhlfeld et al. 2001).

I found that, in the Boise River system, fish captured at the weir in 2000 that were recaptures from the 1999 weir project were aged from 5-7 years old. One of the assumptions about that size class is if they were captured twice going downstream at the weir, the second-year capture indicates that the fish was sexually mature and attempted the spawning migration. If this assumption is valid, then my data supports several studies throughout the Northwest that report the dominant spawning age class as 6 + (Fraley and Shepard 1989, Ratliff et al. 1996, Stelfox 1997). Average adult-sized bull trout captured were 418 mm (TL) which is smaller than average-sized adfluvial adult bull trout in other systems (Fraley and Shepherd 1989, Pratt 1991, Conner et al. 1997). Two possible explanations may account for the difference in mean adult bull trout size between my work and other work in the Northwest. First, I used 300 mm TL as the cut-off value to differentiate adult from juvenile bull trout. I used this length value to be consistent with previous work done in the Boise system (Flatter 2000). This upper size limit would reduce the adult, but increase the juvenile sample size. However, it would not account for the second year post-spawning adult size of 408 mm (assuming that these recaptured fish spawned or made the migration to spawn). Second, Arrowrock and Lucky Peak reservoirs are oligotrophic systems with large drafting events (< 15% of full pool most years) that potentially could limit secondary production. Water column samples showed very low levels of zooplankton and Chlorophyll-a in reservoir tows (USBR unpublished data). Low reservoir productivity may reduce bull trout growth rates when the fish use these reservoirs as overwintering habitat (Conner et al 1997, Beauchamp and Van Tassell 1999). Most drafting in Arrowrock occurs in the fall when bull trout are returning. The concept of major drafting affecting bull trout growth rates is further supported by length frequency data from the Anderson Ranch adfluvial bull trout population. Anderson Ranch is a reservoir system on the South Fork of the Boise River that has a conservation pool and drafting rarely occurs greater than 50% of full pool (USBR 2001b). Anderson Ranch bull trout are 20 to 30 mm longer than those in Arrowrock for each age class group. Bull trout in Anderson Ranch can reach maximum lengths of 730 mm where the largest bull trout captured in Arrowrock was 700 mm (IDFG unpublished data).

Growth data for juvenile size bull trout supports other reported findings (Ratliff et al. 1996, Pratt 1991, Stelfox 1997, Conner et al. 1997). Greatest growth was during the summer season and for fish < 300 mm that were migrating either from the weir to the reservoir or from the screw trap to the weir. The data can be shown to exemplify life history theory where bull trout will migrate to optimize temperature (metabolic) and forage availability that leads to increases in growth. Recapture sample size was low, but juvenile bull trout growth trends were consistent with those of Ratliff and Howell (1992) where, in their study, juvenile bull trout in the reservoir grew an average of 14 mm per month. Growth was highest for the one juvenile bull trout that was marked and recaptured in Crooked River during summer, growing 0.96 mm per day. Seasonal growth was highest for juvenile bull trout moving from the screw trap to the weir trap (17.20 rkm in 2 - 3 months). Reduced juvenile growth rates as temperature increases are documented by Shepard et. al (1984) and McPhail and Murray (1979). Two juvenile bull trout were captured at the weir trap in September and October. Each bull trout had reduced growth rates as time between mark and recapture dates increased. Based on a small sample size, my data may suggest that the greatest growth for juvenile bull trout may occur in June and July, but will decrease as the system reaches maximum temperatures in August.

Adult bull trout migrating from the reservoir to tributaries showed decreases in both weight and length. My growth data for adult bull trout are consistent with other reported findings (Conner et al. 1997, Westover and Baxter 2000). Adult growth was highest in winter as fish return to larger water systems from spawning habitats (annual growth per day = 0.15 mm versus growth per day during the summer months of migration = -0.13 mm). Adult bull trout captured during the spawning season in tributaries experienced very low growth (0.11 mm/day) over the year. Greatest growth must have occurred during winter because adult bull trout that were captured prior to and recaptured following the spawning season lost weight. Growth rates of Arrowrock adult bull trout were lower than those reported for Lake Billy Chinook, Oregon, where adult bull trout were reported to grow 167 mm per year (Ratliff et al. 1996). Growth rates were more similar to Chester Morse Lake, Washington, where the reported range was 30 - 70 mm per year (Conner et al. 1997). Growth rates for the Arrowrock bull trout were also close to those reported for the Wigwam River, British Columbia, where mean growth was 47.3 mm per year for males and 45.4 mm per year for females (Westover and Baxter 2000).

Resorbtion of tissue has been documented in fish species that undergo starvation, or prolonged periods of stress (Brett 1971). My growth data supports the theory of tissue resorbtion to compensate for energy expenditures under low forage ability. The recaptured bull trout lost both weight and length during the migration period. I do recognize that some error could have occurred in field measurement, however it is not apparent in the other sampled fish and the magnitude is rather large. Flatter (2000) documented migration routes into the North Fork with distances greater than 100 km from Arrowrock Reservoir. Bull trout were recaptured at North Fork Boise River rkm 14.8, returning in the post-spawning migration. Bull trout have been documented spawning more than 46 kilometers upstream of the recapture location. Generally, a migrant life history proposes an increased risk in mortality by increasing predation and stress. The risk of migration is offset by increased reproductive success or fecundity due to increased growth. The migrant growth information supports this concept of risk and growth interactions. The bull trout that were captured were relatively large and heavy fish in June, possibly due to overwintering in a reservoir with a large prey base as shown by our total gill net catches. Migration and possible spawning caused a substantial reduction in weight of these bull trout, which may reflect the risk associated with migration.

Environmental Influences

Hughes (1998) describes habitat segregation by salmonids based on fish size and prey availability through invertebrate drift. Hughes suggests that cooler streams with low invertebrate drift densities will have a “large-fish-upstream” distribution pattern, while cool streams with high invertebrate drift will have a “small-fish-upstream” distribution pattern. Hughes work discusses distribution of fish so that a fish will tend to occupy the most profitable position in the stream that it can defend (in terms of food and energy resources) with the largest fish winning any disputes. In my study, most bull trout found in the headwater streams were juvenile size class bull trout. Larger fish were generally not found in small streams until late August during spawning. Hughes discusses a "large fish-upstream" concept of low-density drift feeding, resident salmonids. The Boise River system is a rather oligotrophic, cool water system similar to the Grayling study sites discussed by Hughes. My work shows a "small fish-upstream" which may be indicate higher invertebrate drift densities in the Boise River system. Although juvenile bull trout are generally insectivorous, they become more piscivorous as they grow larger (Pratt 1992, Rieman and McIntyre 1993, Beauchamp and Van Tassell 1999). I did observe size segregation when data was collected higher in the system, which may indicate that there is high invertebrate drift in the system according to Hughes model. I did not sample the extent of invertebrate drift, but if Hughes models are applied, one may conclude that drift densities should be high. I did note size segregation in bull trout movement patterns that also supports Hughes models. Additionally, night and paired adult movement shown by the North Fork bull trout support findings of Fraley and Shepard (1989) who documented night and paired movement of adult bull trout prior to spawning. They noted that juvenile size bull trout moved in large groups and rarely with larger adult bull trout. Behavioral characteristics such as group movement and avoidance of larger bull trout by juveniles may be a survival strategy to avoid predation.

Spawning and early Rearing Habitat

Data from spawning and early rearing streams support the idea that stream width plays a significant role in both presence and absence of bull trout and in the prediction of bull trout density (Rieman and McIntyre 1995, Dunham and Rieman 1999). With the data from these streams, I found a significant correlation between stream width, temperature, elevation, date, and cover. Correlation between dates and some of these variables may be due to the sampling effort, which occurred over two months and moved from low elevation, accessible sites in July to the higher elevation, less accessible sites in August. The Upper North Fork sites are in the Sawtooth Wilderness area and often not accessible until the first week of August in normal water years. In the Columbia River system, juvenile Chinook survival was strongly related to available rearing habitat when river flows changed, stream width was altered and side channel habitat was lost (Garland 2001). Thus, increased flows during wet years increased salmon survival and smolt migration (Garland 2001).

Migration Corridors

My data reflects a possible relationship between bull trout year class strength and declining flow and cumulative precipitation in the river basin. Several year classes of bull trout captured at the weir showed year-to-year trends with the exception of years 1998 - 2000 and 1989 - 1990. These years represent age classes 0+ - 2+ and 9+ - 11+ of bull trout that had low catches resulting from either natural mortality (9+ - 11+ age classes) or low capture rates from gear selectivity.

Sample size poses a problem with making conclusions about the relationship between flow, precipitation, and bull trout year class strength. Variability in precipitation and numbers of bull trout per age class was high, making the power of any statistical test low. However, support for an observed relationship was derived from the fact that year class strength exhibited natural mortality from year to year and strong year classes captured in 1999 aged one year in 2000. Additionally, bull trout life history must also be considered. The dominant adult age class was 6 + in year 1999 and 7 + in year 2000.

However, one would not expect to see large numbers of 5+ age class bull trout in any year. Year classes 4 + and 5 + are reservoir rearing years for adfluvial bull trout and consequently these year classes could have weak captures in migratory corridors (Fraley and Shepherd 1989, Ratliff et al 1996). In my study, these year classes coincided with low water years, and therefore data collected in 2001 and 2002 may give more insight into the actual strength of those year classes. Additional data collected will also add to sample size and may lend support to the observed relationship. The year classes are discerned using data derived from the age class by length regression model. The observed realtionship raises an important question. More work is needed which addresses the question of the influence of water year on bull trout survival.

Temperature has been described as a factor driving the expression of life history forms (migrant versus resident) (Winemiller and Rose 1992, Rieman and Chandler 1999). Temperature impacts migration timing and growth in other salmonids as well (Beacham et al. 1988). In addition, temperature has been shown to be a major factor affecting juvenile bull trout growth (McMahon et al. 1999) and consequently age at maturation and stream survival (Winemiller and Rose 1992). Movement of juvenile bull trout at the North Fork Boise River migratory corridor was related to changes in water temperature. At the North Fork Boise River trap, both mean temperature during the day and mean daily flow described the variation in juvenile bull trout daily catches. The findings for juvenile size bull trout support the contention that temperature is a cue of bull trout life history aspects such as migration (Fraley and Shepherd 1989, Pratt 1992).

There was no significant relationship found for adult bull trout catches with temperature and flow at the North Fork weir trap. One possible explanation is that variation was quite high for adult bull trout catches and sample size of bull trout caught per day was rather low. The low, highly variable sample would yield a weak, if any relationship when modeled. Additionally, the trap was operated from the end of August to the end of October and the data was highly trended to date. Part of the adult migration may have been missed due to the duration of operation, which may increase when temperatures continue to decline and flow becomes more variable in November and December.

Efficiency of Methods

Headwater Streams: spawning and rearing habitat

Capture efficiencies through electrofishing have been shown to vary significantly with stream size and debris, conductivity, flow, fish size and fish densities (Thurow and Schill 1996). By chance, this work occurred across a normal to high water year (1999) and a lower water year (2000). Although crews were unable to sample the high elevation, high density sites, our catches increased significantly in the Crooked and Bear River systems. This could be attributed to significantly reduced water levels.

Stationary Traps: Screw Trap

Rotary screw traps are commonly used to capture salmonids for migration and population research in the Pacific Northwest (Ratliff et. al 1996, Pyzik and Bickford 1997, Madden and Lewis 1999). Work from the Metolius River system found that juvenile migration occurred primarily between May and June and that three age classes were captured in the traps, 0 - 2+ (Ratliff et. al 1996). I captured mostly age class 2+ - 3+ juvenile bull trout with very few bull trout from other age classes. My results differed from what was found in the Metolius trapping projects for several possible reasons. In the migratory corridors of the Boise River Basin, most of the bull trout were captured within the first three weeks of trap operation. This may indicate that the bull trout are moving earlier, before my trapping operation started. Also, physical differences between the Metolius and the Boise River Systems make comparisons of bull trout movement and timing tenuous at best. The Boise River is a predominantly snow-melt system with few springs. My trap was located on a large tributary that is 40 km long. The Metolius is a primarily spring-fed system, with Jack Creek (location of the screw trap used for comparison) approximately 19 km in length (Ratliff et al. 1996). Data for juvenile migration from the Metolius was collected on Jack Creek, a small tributary to the Metolius. Because my trap was located on a much larger, highly fluctuating river system. the captured bull trout may reflect an older age class in a migratory corridor moving toward the reservoir rather than very young bull trout rearing in a headwater stream. Additionally, the trap was operated as long as flows permitted (through August 3), which was a much shorter time than in the Metolius work. I documented larger bull trout escaping from the trap when flows dropped below 12.74 m^3/s in the main-stem Boise River.

The screw trap had very low catch rates for bull trout < 200 mm TL and adult bull trout > 300 mm TL, with most fish captured being 200-300 mm TL. Several possible explanations exist for the poor catches at these size classes. First, the screw trap may favor the capture of smaller fish (< 300 mm TL). Flow rates in August and September at the site would not allow for sufficient rotation of the cone to prevent escapement by larger fish. The smallest bull trout captured was 110 mm TL. Fry were not captured. However, fry predation may have occurred as sufficient cover could not be provided inside of the trap. Additionally, the trap was operated later in the season and could have missed movement of smaller bull trout. Finally, the trap could be located low enough in elevation to allow for temperatures that exceed suitable conditions for fry rearing. The trap could have been located in an area that is only suitable as a migration corridor hence fry were not captured. Finally, the capture data from all methods support the hypothesis that young age classes of bull trout remain rearing in headwater streams during their first three years of life and may not begin migration until age class 3+ (Fraley and Shepard 1989, Pratt 1992, Rieman and McIntyre 1993).

The methods used by Madden and Lewis (1999) were followed to calculate an estimate for the juvenile bull trout recruitment from Crooked River. Crooked River catch efficiencies appear to generally agree with the associated screw trap literature, however; the size classes, timing, and duration of trap operation does not. Additionally, I calculated error associated with my estimate, which gives a large range of the estimate because the recapture rate was very low and efficiencies were based on a recapture of four fish. My estimate for Crooked River recruitment was substantially lower than that of the Metolius River system, but with a wide range. This is most likely due to timing, age classes captured, duration of trap operation, and calculation of error. In my study, crews were unable to install the screw trap until late May due to snow pack. In addition to location and system differences, snow pack levels may account for the differences reflected between my data and the Metolius River (Ratliff et. al. 1996, Madden and Lewis 1999). Suggestions for further work include increasing the trapping time frame with earlier installation. Recapture efficiencies may be increased by adding weir panels adjacent to each side of the cone to possibly reduce trap avoidance by guiding fish to the cone. Increasing trap operation time may help to address some of the age class and timing questions that this operation has raised.

The North Fork Boise River: Migratory Corridor

Temporary weir or fence traps are commonly used to capture salmonids for migration and population research in the Pacific Northwest (Westover and Baxter 1999, Clayton 2000). Very low catch rates were experienced for juvenile bull trout < 200 mm TL at the North Fork Boise River weir traps. Several factors may explain the poor catch at these life stages. First, the weir trap was probably size selective against small bull trout < 200 mm TL. Stelfox (1997) found that many bull trout < 150 mm TL could pass through the 14 mm widths of his picket-style trap. The smallest bull trout found gilled between pickets at the North Fork weir was 220 mm TL, which suggests that smaller bull trout could move through the pickets. Though several bull trout < 200 mm TL were captured in the trap, they represented a small proportion of total weir catch. Second, predation of juveniles in the trap may have occurred, even though a pine bow was placed in one half of the trap area as cover for juvenile fish. Third, juvenile adfluvial bull trout may not move during the autumn and may exhibit strong spring movement thus would be under-represented in the weir catch (Ratliff et al. 1996). Stelfox (1997) found that most juvenile bull trout captured in his weir trap were age class 3+, ranging in size from 151 mm to 200 mm TL. The capture and age groups from my work support Stelfox's results. Additionally, the distribution data from captures across the basin support the hypothesis that young age classes of adfluvial bull trout remain in headwater streams for their first three years of life (age classes 0+ - 2+) and do not begin migration until they are age class 3+ (Fraley and Shepard 1989, Rieman and McIntyre 1993, Stelfox 1997). To better understand bull trout life history and population dynamics, future research needs to focus on juvenile migration and movement in the North Fork system.

I used a conservative mark-recapture statistic (Sheaffer et al.1996) to estimate adult, post-spawning bull trout marked at the weir in 1999 and recaptured in 2000. This statistic is biased because it does not account for changes in natural mortality between years, alternate year spawning patterns that may have existed, maturation/recruitment of juveniles into the spawning population, or straying. I examined a range of possibilities for the population estimate by incorporating immigration and tag loss. Since actual immigration data was unavailable, arbitrary values were used to examine the levels the population would be impacted when maturation rates of juvenile bull trout increased or decreased. The three levels of immigration I used were derived from recapture data from fish tagged at the weir in 2000 and recaptured in 2001, which is currently underway. Generally the estimate decreased with increasing immigration (fewer marked bull trout recaptured the next year), and was amplified by incorporating tag loss (numbers of marked bull trout that would have been recaptured if tag loss did not occur).

A population estimate for juvenile bull trout was not calculated because only two juvenile size bull trout were recaptured at the weir in 2000. Multiple factors could contribute to low capture and recapture of juvenile bull trout. Alternatively, low recapture data for juvenile bull trout could support adfluvial and fluvial life history theory where juvenile bull trout would rear in a reservoir or large river before returning to natal streams to spawn (Pratt 1992, Rieman and McIntyre 1993).

Reservoir Netting

The reservoir netting data indicates that total fish capture and bull trout capture are related to Lucky Peak elevation. Total fish capture was also related to Lucky Peak inflow, which is primarily discharge from Arrowrock Dam. The data indicates that including Lucky Peak reservoir elevation in planned trapping work could decrease trapping time needed to catch optimal numbers of bull trout.

Flatter (2000) documented bull trout CPUE for Lucky Peak in 1997 to be 0.40 (SE = 0.01) that is higher than my estimate of CPUE for the system. Two possible scenarios may explain the difference between the two rates. First, Flatter (2000) also documented increased entrainment during use of the spillway on Arrowrock dam in 1997 (a flood year for the system). The spillway has not been used, or has been used very little since 1997, due to normal or slightly less than normal water years, so bull trout may not have been entrained at high numbers over the last three years. Consequently, fish densities in Lucky Peak would be lower due to natural mortality and lowered recruitment, making catch rates lower. Second, my sampling was conducted over a much longer period of time in order to examine environmental changes with effort. Sampling was much less efficient in early April, this contributed time to my CPUE rates with few bull trout captures. Both explanations show that possible fish density and time-frame need to be considered when seeking high catch efficiencies. Additionally, bull trout may be easier to capture during late May and June: these months are associated with the initiation of spawning migration (Flatter 2000). Adult bull trout may be staging near attraction water such as the water coming from the valves during this period and that is possibly the reason catch rates were best immediately below Arrowrock Dam. Flatter (2000) also documented high captures near Arrowrock during the months of May and June.

Both Arrowrock and Lucky Peak reservoirs were created in steep canyons, with highly granitic soils. The operations of both reservoirs for Boise valley irrigation prevent riparian vegetation and autotrophic production from increasing due to steep drafting (up to 83% of full pool draw-down) in fall and slow refill over winter. Consequently, both reservoirs have steep shorelines with little vegetation and cover for fish. Gill nets work well when operated under these reservoir conditions: little debris and mobile fish. There was no documented mortality in bull trout from the gill nets, but some sucker and whitefish were killed when densities were high and it took substantial time to remove the fish from the nets.

Overall, efficiencies in capture were found to be increased substantially by limiting the time period of effort to where Lucky Peak reservoir elevation is near 930 msl and time frame is late May and early June. Suggestions for future work include adding other methods of capture and repeating this year's gill net effort to support the 2000 findings. Since temperature has been documented to be an important factor keying migration, using temperature as an independent variable may additionally yield some insight into optimal timing for catches.

Age and Growth

Each capture method selected for fish of different lengths. This is also apparent when age was regressed on length for each method separately. Several explanations exist for the size class and method differences. First, scale age by length models were weak for the reservoir netting sample due to small samples in size and in representative age classes. For example, one age class was representative of over half of the entire sample and only one fish was representative of two of the other four age classes. Consequently the model had low variation and a insignificant p-value. The same errors shown in the reservoir netting also most likely occurred with the screw trap effort. The data did not include scales from many bull trout < 200 mm TL or > 300 mm TL. Consequently, the data does not accurately reflect length ranges since only two close length and age classes were modeled. Length at age models for the screw trap alone were not significant because only two age classes were represented, and only one bull trout was representative of age class 1+. When bull trout from the tributary and river system samples were combined to create new models, there were substantial increases in the accounted for variation and the model p-value was significant. This shows that the range and sample size was insufficient for the reservoir and screw trap bull trout when modeled alone. The weir model for age-length relationships was the most complete, with 10 age classes represented. However, small sized bull trout were under-represented. Weir-captured bull trout length at age regressions did not include scales from many bull trout < 200 mm TL and consequently do not accurately reflect length ranges for 0+ - 1+ age classes.

The age at length models were linear so they did not reflect actual salmonid lengths and would be most useful if juvenile size classes are distinguished from adults. Statistical models for younger, tributary captured fish had much steeper slopes indicative of the faster growth rates than the large fish or combined capture models (which can be shown to be reflected in the growth per day information for small fish). One explanation is that the models give a rough reflection of growth rates over the time. These simple linear models show incremental increases in length which are related to incremental increases in age. Since juvenile bull trout are expected to grow faster than adults, the slopes for small bull trout models will be steeper than large fish models.

Implications for Management

The findings of this study have important implications for land management actions as well as water use and reservoir operations. Habitat condition has been discussed as a major contributing factor contributing to the distribution and abundance of bull trout populations (Pratt 1992, Rieman and McIntyre 1993). Significant relationships were found for bull trout captures as they related to environmental conditions across all sample areas. Large-scale water levels (precipitation and flow) were found to have significant relationships with juvenile bull trout captures and observed to have a possible influence on year class strength. Temperature and available side channel refugia vary with water levels (Garland 2001). Therefore, greater juvenile survival during years where water levels may be higher might be expected. This concept was the focus when I assessed the relationship that year class strength may have with accumulated precipitation, spring flow, and temperature. My study data suggests that egg, fry, or alevin mortality levels could be linked to annual precipitation and flow. My findings support those of Fraley and Shepard (1989) that report migration keyed to specific temperature ranges. The Boise Basin bull trout populations inhabit a highly stochastic natural environment. My data supports the theory that conservation of a wide variety of habitats and a large range of habitats must be maintained by natural resource management agencies.

This study has implications for management related issues where changes in reservoir operations can maintain elevated or improved water conditions. The question of the the magnitude of influence that precipitation levels have on survival of bull trout becomes particularly important for management. If there is a strong relationship between low precipitation and low survival, improved reservoir conditions would be especially important for bull trout to compensate for dry water years in headwater streams. The current conditions in year 2001 in the Boise River provide an excellent template for the examination of drought versus flood impacts and reservoir levels. Current accumulated precipitation levels are listed as 52% of normal years (Ted Day, USBR, personal communication). With the proposed Arrowrock Dam valve replacement project (duration 2001-2003), drafting will be considerably less during the first two years of the project in 2001 and 2002 (USBR 2001b). However, the third year of construction requires a near complete evacuation of Arrowrock reservoir (99.8% of full pool, USBR 2001). The reservoir evacuation comes at a time when egg, alevin, and fry mortality is could be high (low precipitation, weak age classes (0+, 1+, and 2+). If large-scale drafting would yield greater entrainment and reduced numbers of migrating fish, then North Fork Boise River weir captures for adult bull trout should be substantially lower following the project in 2004 and 2005. If precipitation does have a strong influence on survival then reduced numbers of juvenile bull trout is predicted in the Boise River system in 2003, 2004 and 2005. As a result of the current drought, the proposed reservoir drafting in Arrowrock planned in 2003 could have serious effects to the North and Middle Fork Boise River adfluvial bull trout populations.

My data raises questions about the strength of the relationship between drought and young fish survival. Arrowrock reservoir is anticipated to be nearly completely evacuated, entraining a large component of the reservoir rearing and adult overwintering bull trout at the same time that drought may have caused reduced survival of tributary rearing juveniles. The combination of these conditions places emphasis on the need to trap and transport large numbers of the entrained bull trout from Lucky Peak to Arrowrock Reservoir. Methods to reduce fish mortality associated with the trapping and entrainment must be considered. My work raises questions about juvenile survival in the tributaries and how it relates to drought years. Work that addresses these questions would not only add to our knowledge of the influences on natural conditions which affect bull trout populations, but aid in planning land and water use projects that affect bull trout. Recommendations include continuation of work to monitor bull trout populations in the Boise over the next four years to add support to these findings as well as identify methods to reduce mortality associated with trapping and entrainment.

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APPENDIX A

Flow and Temperature Measurement Comparison Between Years and Methods of Collection

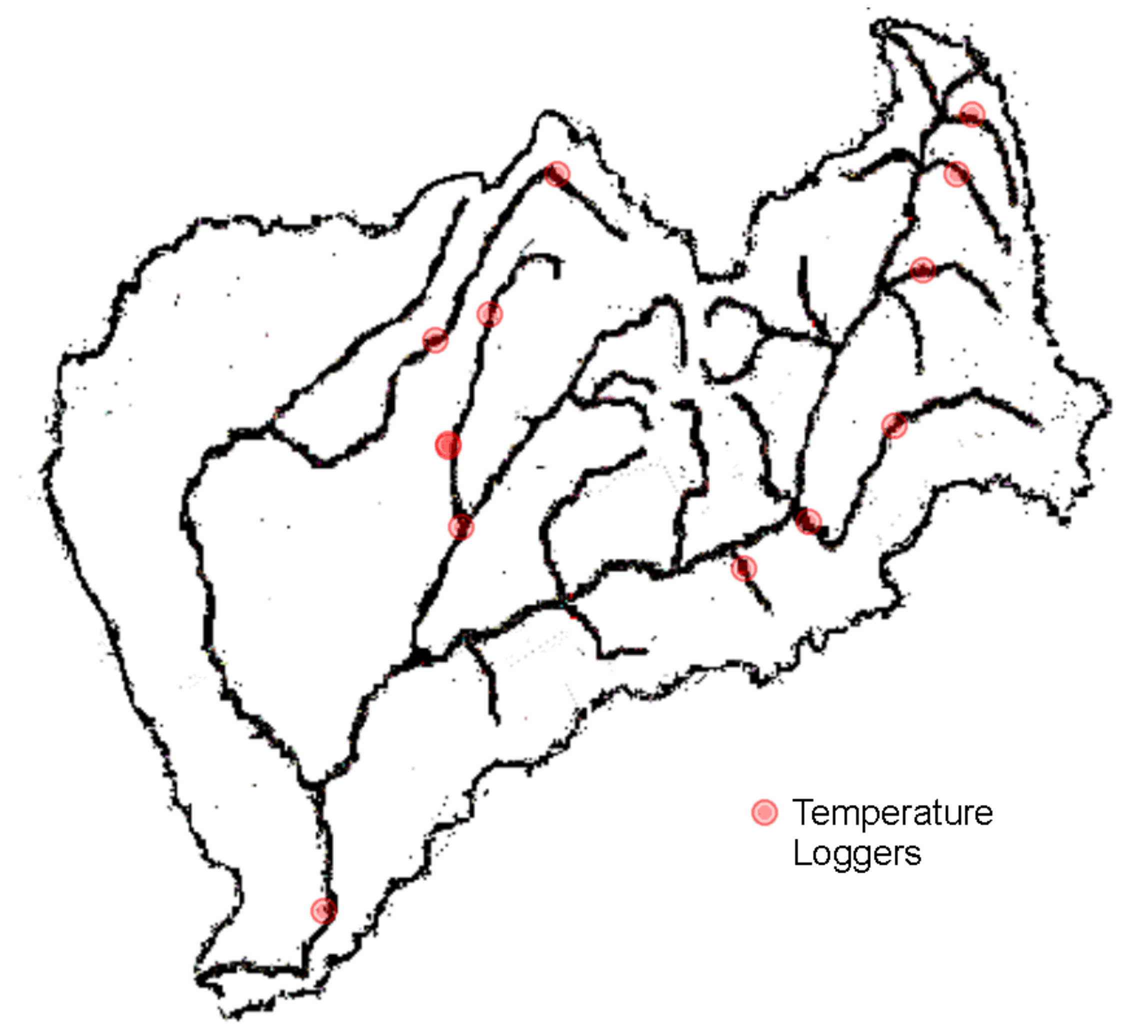


Figure 1.A Locations of temperature loggers in tributary streams of the North Fork Boise River.

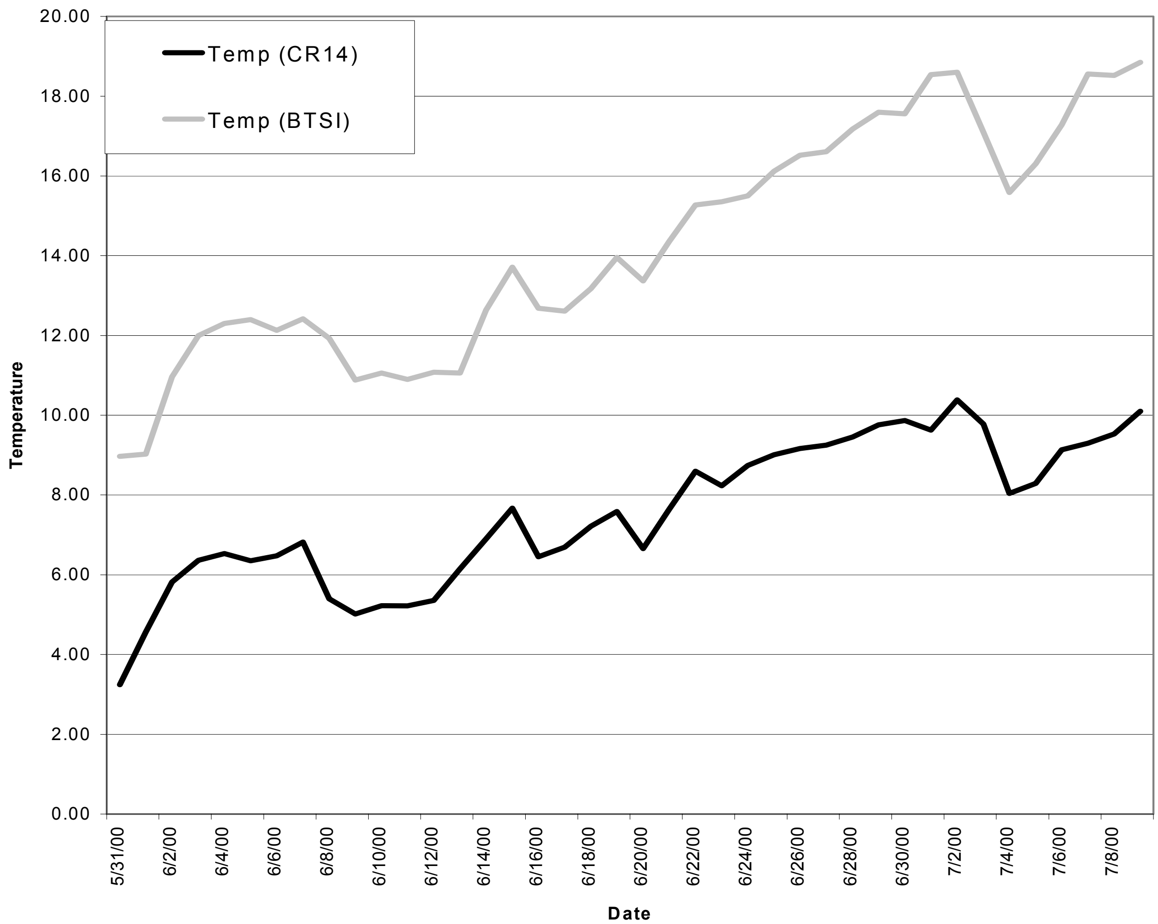


Figure 2.A Comparison of temperature reported from loggers located at Crooked River km 21.5 (CR14) and North Fork Boise River km 0 (BTSI).

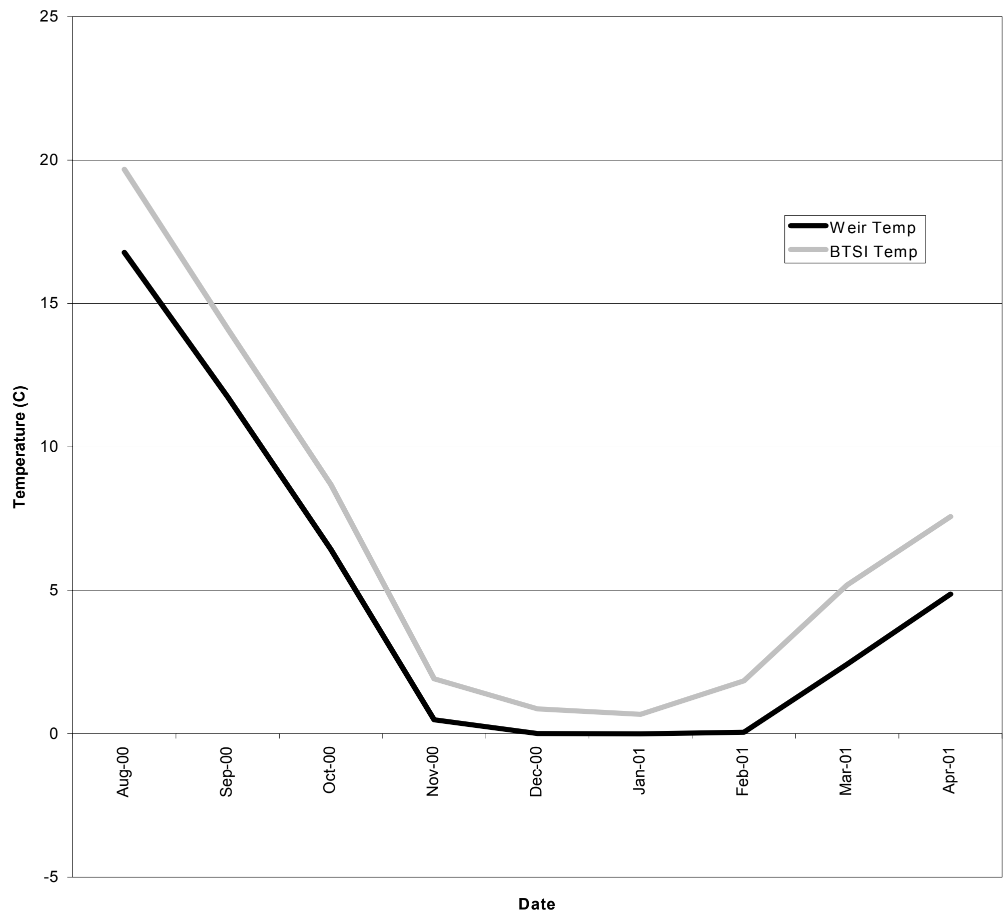
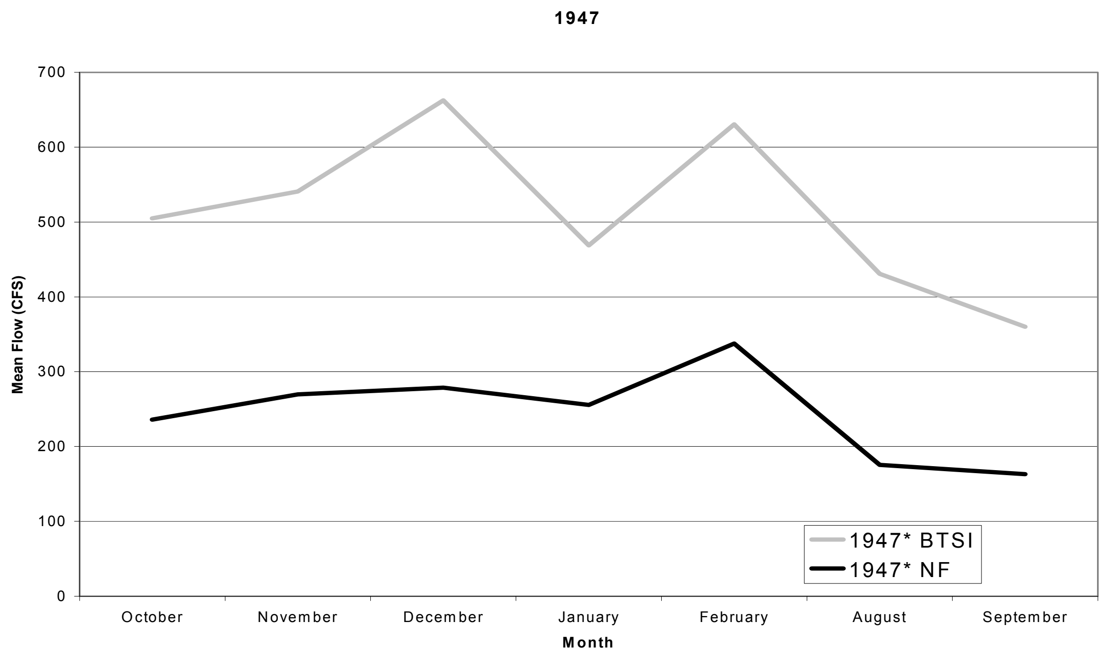


Figure 3.A Tidbit temperature logger located at the North Fork weir (river km 15) compared to the U.S. Bureau of Reclamation Hydromet gauge BTSI (river km 0)



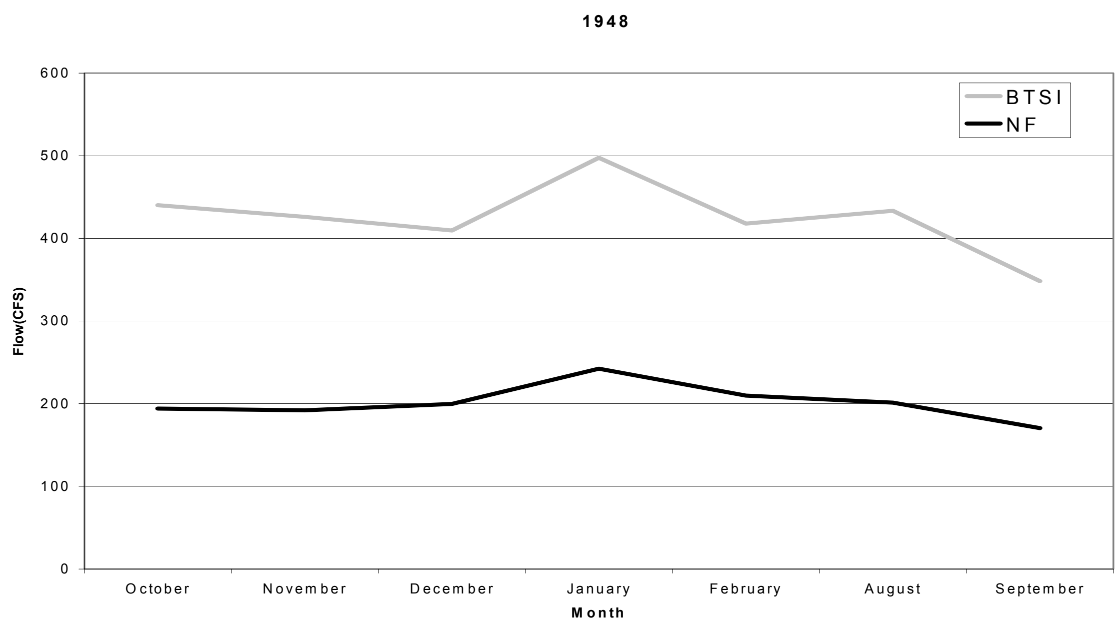


Figure 4.A Historical flow data for comparison of North Fork Boise River and Middle Fork Boise River (BTSI) Discharge. **Note the North Fork Gauge has expired.

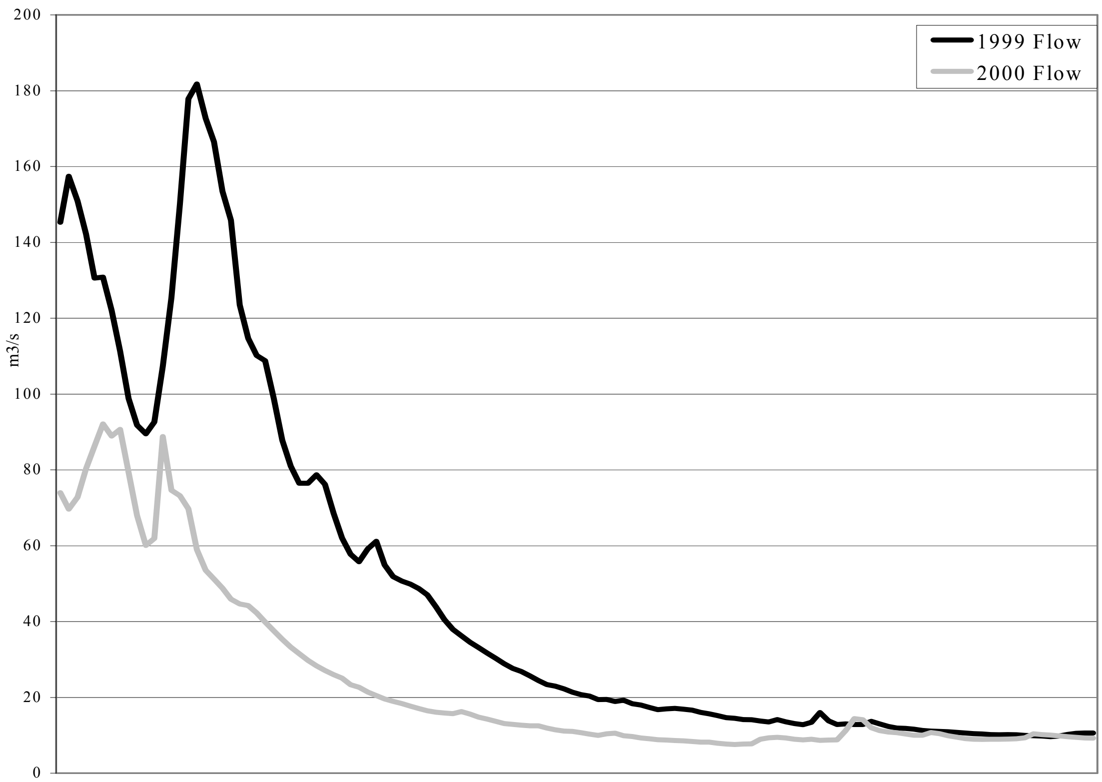


Figure 5.A Spring discharge recorded for years 1999 and 2000 at Hydromet gauge BTSI at North Fork Boise River km 0.

APPENDIX B

Headwater Streams Habitat Variables and Pearson Correlation Coefficients

List 1.B Description of habitat variables used in Correlation analyses (Total of 16)

1. N = Number of bull trout estimated with Seber-LeCren method
2. V = Variance of bull trout caught
3. q = Catchability
4. Vq = Variance of Catchability
5. bt = Bull Trout per 100m²
6. btadj = Bull Trout per 100m² adjusted for Catchability
7. width = Stream Site Width
8. LWDC = Large Wood Debris Total Cover
9. COVHVEG = Overhanging Vegetation Total Cover
10. CUNCBK = Undercut Bank Total Cover
11. TCOVER = Total Cover per site (vegetation, wood debris, undercut banks)
12. pcov = Percent Cover (Cover area to Site area)
13. date = Date
14. ele = Elevation
15. temp = Temperature (Average 7-day annual maximum)
16. cond = Conductivity

Table 1.B List of habitat variables measured and calculated from all electrofishing site data

Variable #	Variable	Description
1	Temp	One time temperature reading or gauge data if available
2	Channel Type	Rosgen Channel Type
3	Gradient	Calculated from Arcview or from USGS topo maps, rise over run*100
4	Pool Frequency	Number of pools per mile based on length of site and number of pools
5	% Pools	Number of pools divided by total pools and riffles in 100 m length of site
6	% Cover	Total cover area divided by total pool area for each site
7	Total Cover	Sum of areas for all cover types (wood, vegetation, banks)
8	Undercut Bank	Length, Width, and calculated area of undercut bank (>0.3 m in width or wider only)
9	Overhanging vegetation	Length, Width, and calculated area of overhanging vegetation (no > 0.5 m from water surface)
10	Large woody debris	Length, Width, and calculated area of large woody debris (>0.3 m or larger in width only)
11	% Fines	Counted with grid and described in Methods
12	Conductivity	Taken at time of sampling, in uS
13	Width:Depth	slow water width to depth ration
14	Width:Max. Depth	Slow water max width to depth ration
15	Fast Water Depth	Mean depth
16	Fast Water Width	Wetted width
17	Fast Water Length	Total length between formations of adjacent types
18	Slow Water Depth	Mean depth
19	Slow Water Width	Wetted width
20	Slow Water Length	Total length between formations of adjacent types
21	Slow Water Max Depth	Deepest section of pool
22	Slow Water Crest Depth	Depth at tail of pool
23	Large Pool	Area of pool deeper than 0.3 m
24	Elevation	in meters from USGS topo maps
25	Brook Trout / 100 m^2	Two pass estimates and size differentiation was made for listed fish
26	Bull Trout / 100 m^2	Two pass estimates and size differentiation was made for listed fish
27	Whitefish / 100 m^2	Two pass estimates and size differentiation was made for listed fish
28	Cutthroat Trout / 100 m^2	Two pass estimates and size differentiation was made for listed fish
29	Rainbow Trout / 100 m^2	Two pass estimates and size differentiation was made for listed fish

Tables 2-11.B Pearson Correlation Coefficients for habitat variables used in regression analyses for predicting density of bull trout by habitat variables.

Table 2.B Pearson Correlation Coefficients and Significance Values
Significance Values in Italic

	N	V	q	Vq	btdns	btadj
N	1.00	0.93	-0.47	-0.02	0.96	0.41
	<.0001	*0.01*	*0.92*	*<.0001*	*0.02*	
V	0.93	1.00	-0.32	-0.02	0.84	0.14
	<.0001	*0.07*	*0.90*	*<.0001*	*0.45*	
q	-0.47	-0.32	1.00	-0.69	-0.50	-0.16
	0.01	*0.07*	*<.0001*	*0.00*	*0.38*	
Vq	-0.02	-0.02	-0.69	1.00	-0.01	-0.21
	0.92	*0.90*	*<.0001*	*0.94*	*0.24*	
btdns	0.96	0.84	-0.50	-0.01	1.00	0.50
	<.0001	*<.0001*	*0.00*	*0.94*	*0.00*	
btadj	0.41	0.14	-0.16	-0.21	0.50	1.00
	0.02	*0.45*	*0.38*	*0.24*	*0.00*	
Width	-0.17	-0.04	0.26	0.04	-0.29	-0.49
	0.35	*0.83*	*0.14*	*0.82*	*0.11*	*0.00*

Table 3.B Pearson Correlation Coefficients and Significance Values
Significance Values in Italic

	Width	LWDC	COVHVEG	CUNCBK	TCOVER	pcov
N	-0.17	-0.18	-0.17	-0.12	-0.22	-0.18
	0.35	*0.32*	*0.35*	*0.51*	*0.24*	*0.31*
V	-0.04	-0.05	-0.11	-0.07	-0.09	-0.11
	0.83	*0.80*	*0.56*	*0.70*	*0.64*	*0.53*
q	0.26	-0.04	0.13	0.09	0.04	0.10
	0.14	*0.83*	*0.47*	*0.61*	*0.83*	*0.60*
Vq	0.04	0.41	-0.01	0.12	0.31	0.02
	0.82	*0.02*	*0.97*	*0.53*	*0.08*	*0.93*
btdns	-0.29	-0.22	-0.19	-0.09	-0.25	-0.17
	0.11	*0.22*	*0.30*	*0.62*	*0.17*	*0.34*
btadj	-0.49	-0.44	-0.18	-0.20	-0.42	-0.22
	0.00	*0.01*	*0.31*	*0.27*	*0.02*	*0.23*
Width	1.00	0.22	-0.02	-0.01	0.15	-0.26
	0.23	*0.92*	*0.96*	*0.42*	*0.15*	

Table 4.B Pearson Correlation Coefficients and Significance Values
Significance Values in Italic

	N	**V**	**q**	**Vq**	**btdns**	**btadj**
LWDC	-0.18	-0.05	-0.04	0.41	-0.22	-0.44
	0.32	*0.80*	*0.83*	*0.02*	*0.22*	*0.01*
COVHVEG	-0.17	-0.11	0.13	-0.01	-0.19	-0.18
	0.35	*0.56*	*0.47*	*0.97*	*0.30*	*0.31*
CUNCBK	-0.12	-0.07	0.09	0.12	-0.09	-0.20
	0.51	*0.70*	*0.61*	*0.53*	*0.62*	*0.27*
TCOVER	-0.22	-0.09	0.04	0.31	-0.25	-0.42
	0.24	*0.64*	*0.83*	*0.08*	*0.17*	*0.02*
pcov	-0.18	-0.11	0.10	0.02	-0.17	-0.22
	0.31	*0.53*	*0.60*	*0.93*	*0.34*	*0.23*
Date	0.26	0.07	-0.14	-0.24	0.28	0.67
	0.16	*0.71*	*0.46*	*0.18*	*0.11*	*<.0001*
Ele	0.38	0.30	-0.33	0.10	0.41	0.25
	0.03	*0.09*	*0.06*	*0.57*	*0.02*	*0.17*

Table 5.B Pearson Correlation Coefficients and Significance Values
Significance Values in Italic

	Width	**LWDC**	**COVHVEG**	**CUNCBK**	**TCOVER**	**pcov**
LWDC	0.22	1.00	0.30	0.46	0.91	0.28
	0.23	*0.09*	*0.01*	*<.0001*	*0.12*	
COVHVEG	-0.02	0.30	1.00	0.19	0.64	0.81
	0.92	*0.09*	*0.30*	*<.0001*	*<.0001*	
CUNCBK	-0.01	0.46	0.19	1.00	0.56	0.19
	0.96	*0.01*	*0.30*	*0.00*	*0.30*	

Table 6.B Pearson Correlation Coefficients and Significance Values
Significance Values in Italic

	Width	**LWDC**	**COVHVEG**	**CUNCBK**	**TCOVER**	**pcov**
TCOVER	0.15	0.91	0.64	0.56	1.00	0.55
	0.42	*<.0001*	*<.0001*	*0.00*	*0.00*	
pcov	-0.26	0.28	0.81	0.19	0.55	1.00
	0.15	*0.12*	*<.0001*	*0.30*	*0.00*	
Date	-0.22	-0.43	-0.45	-0.21	-0.52	-0.43
	0.24	*0.01*	*0.01*	*0.25*	*0.00*	*0.01*
Ele	-0.26	-0.32	-0.27	-0.33	-0.39	-0.10
	0.16	*0.07*	*0.14*	*0.07*	*0.03*	*0.60*

Table 7.B Pearson Correlation Coefficients and Significance Values
Significance Values in Italic

	N	**V**	**q**	**Vq**	**btdns**	**btadj**
tmp	-0.38	-0.30	0.33	-0.10	-0.41	-0.25
	0.03	*0.09*	*0.06*	*0.57*	*0.02*	*0.17*
cond	-0.18	-0.08	0.17	0.07	-0.17	-0.15
	0.33	0.67	0.37	0.71	0.35	0.42

Table 8.B Pearson Correlation Coefficients and Significance Values
Significance Values in Italic

	Width	**LWDC**	**COVHVEG**	**CUNCBK**	**TCOVER**	**pcov**
tmp	0.26	0.32	0.27	0.33	0.39	0.10
0.16	0.07	0.14	0.07	0.03	0.60	
cond	-0.20	0.15	0.38	0.10	0.28	0.44
	0.27	0.40	0.03	0.58	0.13	0.01

Table 9.B Pearson Correlation Coefficients and Significance Values
Significance Values in Italic

	Date	**Ele**	**tmp**	**cond**
tmp	-0.24	-1.00	1.00	0.34
	0.19	*<.0001*	*0.06*	
cond	-0.55	-0.34	0.34	1.00
	0.00	*0.06*	*0.06*	

Table 10.B Pearson Correlation Coefficients and Significance Values
Significance Values in Italic

	Date	**Ele**	**tmp**	**cond**
LWDC	-0.43	-0.32	0.32	0.15
	0.01	*0.07*	*0.07*	*0.40*
COVHVEG	-0.45	-0.27	0.27	0.38
	0.01	*0.14*	*0.14*	*0.03*
CUNCBK	-0.21	-0.33	0.33	0.10
	0.25	*0.07*	*0.07*	*0.58*
TCOVER	-0.52	-0.39	0.39	0.28
	0.00	*0.03*	*0.03*	*0.13*
pcov	-0.43	-0.10	0.10	0.44
	0.01	*0.60*	*0.60*	*0.01*
Date	1.00	0.24	-0.24	-0.55
	0.19	*0.19*	*0.00*	
Ele	0.24	1.00	-1.00	-0.34
	0.19	*<.0001*	*0.06*	

Table 11.B Pearson Correlation Coefficients and Significance Values
Significance Values in Italic

	Date	**Ele**	**temp**	**cond**
N	0.26	0.38	-0.38	-0.18
	0.16	*0.03*	*0.03*	*0.33*
V	0.07	0.30	-0.30	-0.08
	0.71	*0.09*	*0.09*	*0.67*
q	-0.14	-0.33	0.33	0.17
	0.46	*0.06*	*0.06*	*0.37*
Vq	-0.24	0.10	-0.10	0.07
	0.18	*0.57*	*0.57*	*0.71*
btdns	0.28	0.41	-0.41	-0.17
	0.11	*0.02*	*0.02*	*0.35*
btadj	0.67	0.25	-0.25	-0.15
	<.0001	*0.17*	*0.17*	*0.42*
Width	-0.22	-0.26	0.26	-0.20
	0.24	*0.16*	*0.16*	*0.27*

APPENDIX C

Species Composition of Captures Listed by Method and Year

Table 1.C Capture Composition of fishes for each method and year

Species	Electrofishing 1999	Electrofishing 2000	Weir 1999	Weir 2000	Screwtrap 2000	Reservoir 2000
Bull Trout (*Salvelinus confluentus*)	203	199	264	434	57	26
Rainbow trout (*Oncorhynchus mykiss*)	177	241	142	127	170	37
Mountain whitefish (*Prosopium williamsoni*)	3	2	168	123	17	26
Westslope cutthroat (*Oncorhynchus clarki lewisi*)	12	21	2	1	0	7
Brook trout (*Salvelinus fontinalis*)	35	28	3	0	5	0
Sculpin sp.(*Cottus sp.)*	60	353	0	0	0	0
Largescale sucker (*Catostomus macrocheilus*)	0	0	12	1	0	815
Pikeminnow (*Ptychocheilus oregonensis*)	0	0	32	7	0	218
Bridgelip sucker(*Catostomus columbianus*)	0	0	0	0	0	24
Kokanee trout (*Oncorhynchus nerka*)	0	0	0	0	0	2
Smallmouth bass (*Micropterus dolomieui*)	0	0	0	0	0	7

APPENDIX D

Regression and Discriminant Function Model Results: Length by Age, and Environmental Models

Table 1.D Linear Discriminate Function model results for predicting presence of absence of bull trout in the tributary streams based on habitat variables.

1999 Model Results			
Number of Observations and Percent Classified into Group (P/A)			
	Present		
	Accurate Classification	Misclassified	Total
Absent	15	5	20
Percent	75	25	100
	Absent		
Present	28	4	32
Percent	87.5	12.5	100

2000 Model Results			
Number of Observations and Percent Classified into Group (P/A)			
	Present		
	Accurate Classification	Misclassified	Total
Observations	17	4	21
Percent	80.95	19.05	100
	Absent		
Present	18	5	23
Percent	78.26	21.74	100

Table 2.D Headwater Streams: Age by length regression model for bull trout captured by electrofishing

Source	DF	Sum of Squares	Mean Square	F Value	PR > F
Model	1	68.68906	68.68906	249.14	< .0001
Error	107	29.50049	0.27571		
Corrected total	108	98.18954			
Root MSE	0.52508	**R-Square**	0.6996		
Dependent mean	1.88073	**Adj R-Sq**	0.6967		
Coeff Var	27.91871				
Variable	**DF**	**Parameter estimate**	**Standard error**	**t Value**	**Pr > |t|**
Intercept	1	-3.73219	0.35914	-10.39	<.0001
srlength	1	0.47373	0.03001	15.78	<.0001

Regression Model Line: Age = -3.73 + .47 SQRT(length)

Table 3.D Stationary Traps: Age by length regression model for bull trout captured by the rotary screw trap

Source	DF	Sum of Squares	Mean Square	F Value Pr	PR > F
Model	1	0.73156	0.73156	0.72	0.4017
Error	47	48.01334	1.02156		
Corrected total	48	48.7449			
Root MSE	1.01072	**R-Square**	0.015		
Dependent mean	3.0898	**Adj R-Sq**	-0.0059		
Coeff Var	32.71163				
Variable	**DF**	**Parameter estimate**	**Standard error**	**t Value**	**Pr > |t|**
Intercept	1	0.31323	3.28424	0.1	0.9244
lglength	1	0.20231	0.23907	0.85	0.4017

Regression Model Line: Age = 0.31 + 0.20 SQRT(length)

Table 4.D Stationary traps: Age by length regression model for bull trout captured by weir.

Source	DF	Sum of Squares	Mean Square	F Value Pr	PR > F
Model	1	229.60094	229.60094	395.94	<.0001
Error	314	182.08649	0.57989		
Corrected total	315	411.68744			
Root MSE	0.76151	R-Square	0.5577		
Dependent mean	4.29715	Adj R-Sq	0.5563		
Coeff Var	17.72121				
Variable	**DF**	**Parameter estimate**	**Standard error**	**t Value**	**Pr > |t|**
Intercept	1	-1.98472	0.31859	-6.23	<.0001
srlength	1	0.36913	0.01855	19.9	<.0001

Regression Model Line: Age = -1.98 + .37 SQRT(length)

Table 5.D Reservoir Netting: Age by length regression model for bull trout captured by electrofishing

Source	DF	Sum of Squares	Mean Square	F Value Pr	PR > F
Model	1	3.51417	3.51417	2.71	0.1193
Error	16	20.76194	1.29762		
Corrected total	17	24.27611			
Root MSE	1.13913	R-Square	0.1448		
Dependent mean	6.37222	Adj R-Sq	0.0913		
Coeff Var	17.87652				
Variable	**DF**	**Parameter estimate**	**Standard error**	**t Value**	**Pr > |t|**
Intercept	1	1.10529	3.21176	0.34	0.7352
lglength	1	0.2455	0.14918	1.65	0.119

Regression Model Line: Age = 1.05 + ..5 SQRT(length)

Table 6.D Combined Capture Model: Age by length regression model for bull trout captured by electrofishing

Source	DF	Sum of Squares	Mean Square	F Value Pr	PR > F
Model	1	918.79225	918.79225	1730.09	<.0001
Error	488	259.15959	0.53106		
Corrected total	489	1177.95184			

Root MSE	0.72874	**R-Square**	0.78
Dependent mean	3.70408	**Adj R-Sq**	0.7795
Coeff Var	19.67402		

Variable	DF	Parameter estimate	Standard error	t Value	Pr > |t|
Intercept	1	-3.02295	0.16505	-18.32	<.0001
lglength	1	0.42812	0.01029	41.59	<.0001

Regression Model Line: Age = -3.02 + 0.43 SQRT(length)

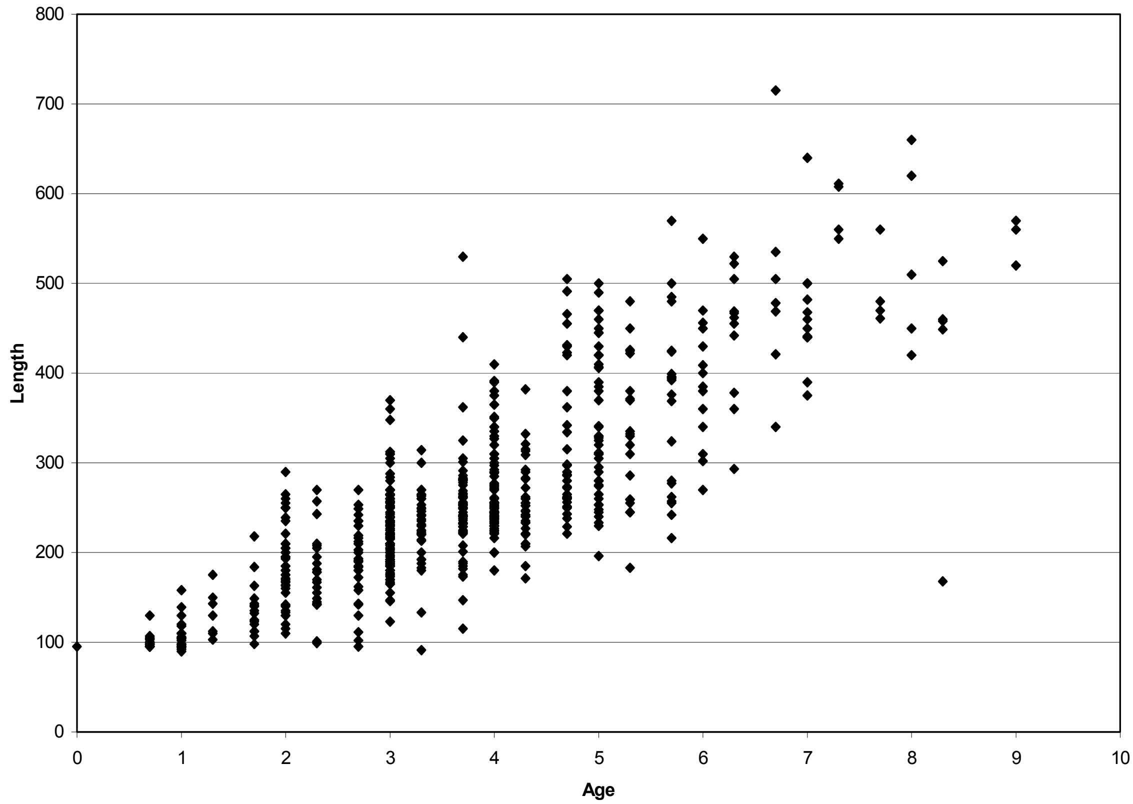


Figure 1.D Scatterplot of all age by length data. Age groups are means of three reader observations.

Table 7.D Bull Trout Densities at electrofished sites and environment, 1999 Data

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	3	595.186	198.3953	8.43	0.0004
Error	28	658.60557	23.52163		
Corrected Total	31	1253.79157			
Root MSE	4.84991	R-Square	0.4747		
Dependent Mean	3.40416	Adj R-Sq	0.4184		
Coeff Var	142.4703				
		Parameter estimates			
Variable DF	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	1365.75808	351.7198	3.88	0.0006
TCOVER	1	-0.07594	0.04322	-1.76	0.0898
logtmp	1	-323.75019	81.34968	-3.98	0.0004
Ele	1	-0.30851	0.08268	-3.73	0.0009

Table 8.D Screw Trap Catch and Temperature Regression

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	1	22.11375	22.11375	44.37	<.0001
Error	41	20.43575	0.49843		
Corrected Total	42	42.5495			
Root MSE	0.706	R-Square	0.5197		
Dependent Mean	1.10426	Adj R-Sq	0.508		
Coeff Var	63.93381				
		Parameter estimates			
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	4.17814	0.47388	8.82	<.0001
temp	1	-0.40073	0.06016	-6.66	<.0001

Table 9.D Residuals of catch per day with date at the Crooked River screw trap modeled with temperature residuals at a 5-day delay

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	1	0.83036	0.83036	1.21	0.2788
Error	36	24.72459	0.68679		
Corrected Total	37	25.55495			
Root MSE		0.82873	R-Square	0.0325	
Dependent Mean	n	-0.00524	Adj R-Sq	0.0056	
Coeff Var		-15817			
		Parameter Estimates			
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	-0.0013	0.13449	-0.01	0.992
lagtemp	1	0.07777	0.07073	1.1	0.278

Table 10.D 5-day average adult (> 300 mm TL) weir captures (10-day delay) with mean daily flow and temperature

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	80.80528	40.40264	11.41	<.0001
Error	57	201.75205	3.53951		
Corrected Total	59	282.55733			
Root MSE	1.88136	R-Square	0.286		
Dependent Mean	2.47333	Adj R-Sq	0.2609		
Coeff Var	76.06571				

Parameter estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	12.78748	2.36358	5.41	<.0001
temp	1	-0.37835	0.08177	-4.63	<.0001
flow	1	-0.53325	0.15673	-3.4	0.0012

Table 11.D Residual model of catch per day, temperature, and flow from for adult bull trout

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	0.37168	0.18584	0.02	0.9812
Error	50	488.6811	9.77362		
Corrected Total	52	489.0528			
Root MSE	3.12628	R-Square	0.0008		
Dependent Mean	0.29468	Adj R-Sq	-0.0392		
Coeff Var	1060.909				

Parameter estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.2989	0.43032	0.69	0.495
temp	1	-0.04546	0.2672	-0.17	0.8656
flow	1	0.01603	0.30166	0.05	0.9578

Table 12.D 5-day juvenile (< 300 mm TL) weir captures with temperature and flow

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	2	367.65853	183.8293	16.14	<.0001
Error	57	649.0848	11.38745		
Corrected Total	59	1016.74333			
Root MSE	3.37453	R-Square	0.3616		
Dependent Mean	4.78333	Adj R-Sq	0.3392		
Coeff Var	70.54767				
		Parameter estimates			
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	18.76932	10.6458	1.76	0.083
logtemp	1	4.07098	1.73431	2.35	0.022
logflo	1	-10.16616	3.27512	-3.1	0.003

Table 13.D Residuals of catch per day of juvenile bull trout with temperature and flow at the North Fork weir trap

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	2	111.22641	55.6132	29.15	<.0001
Error	51	97.29313	1.90771		
Corrected Tota	53	208.51954			
Root MSE	1.3812	R-Square	0.5334		
Dependent Mean	5.56E-06	Adj R-Sq	0.5151		
Coeff Var	24861567				
		Parameter Estimates			
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.00000416	0.18796	0	1.00
flow	1	-0.7549	0.12494	-6.04	<.0001
temp	1	-0.7363	0.1165	-6.32	<.0001

Table 14.D CPUE and Lucky Peak Elevation and Inflow Regression

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	2	5598.797	2799.398	7.12	0.0033
Error	27	10618	393.2594		
Corrected Total	29	16217			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	8968.274	2495.572	5078.749	12.91	0.0013
lucele	-2.89745	0.81294	4995.621	12.7	0.0014
lucinf	-0.02085	0.00727	3236.477	8.23	0.0079

R-Square = 0.3452 and C(p) = 1.2705

APPENDIX E

Headwater Stream Sites and Locations

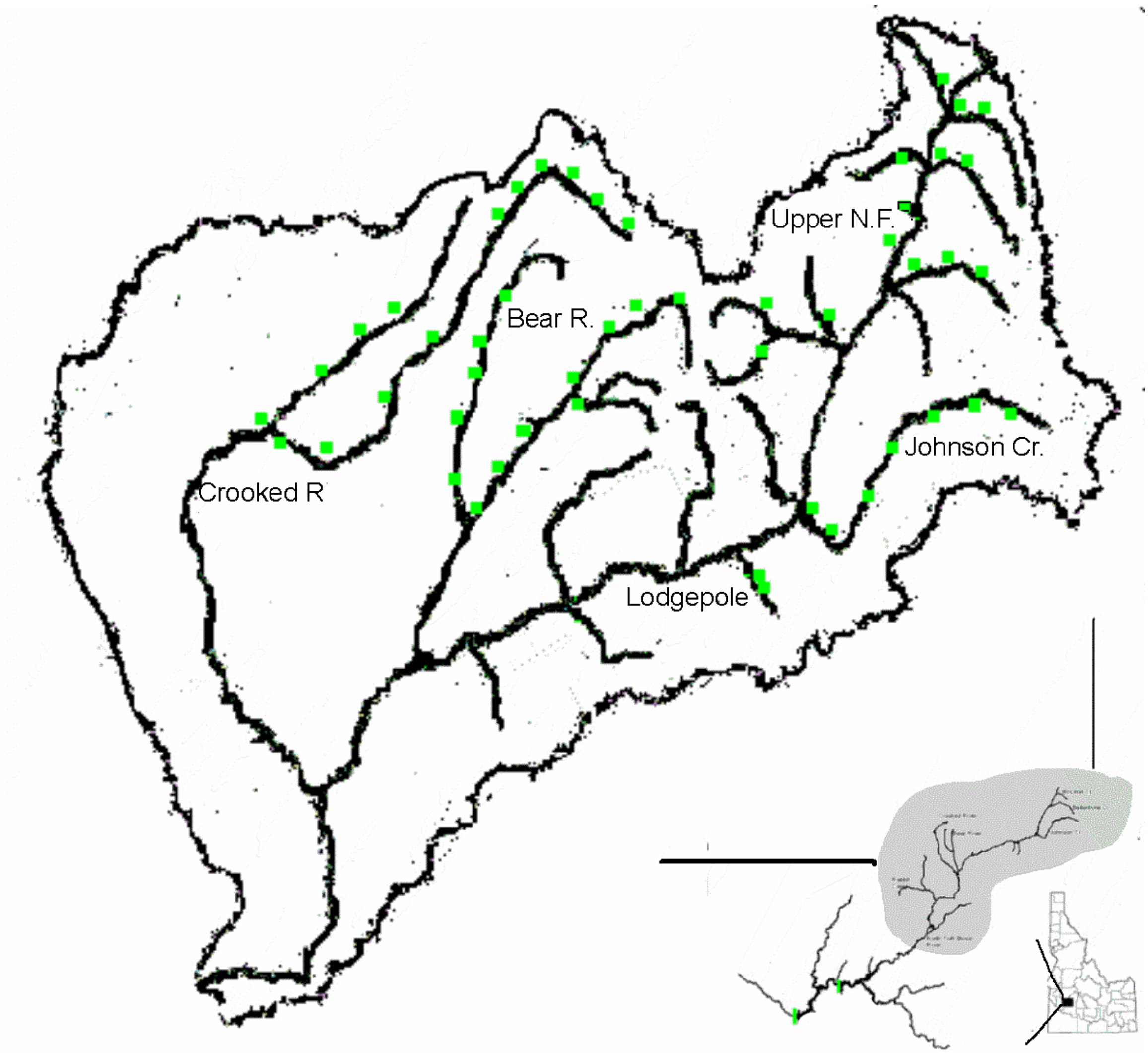


Figure 1.E Map of headwater stream electrofishing sites in the North Fork Boise River Basin. Squared symbols represent approximate electrofishing site locations.

Table 1.E Headwater stream site identifications and elevations

Stream Name	Site Identification	Site Elevation (m)
Arrastra Cr.	Arr0	2073
Banner Cr.	Ba0.5	1609
Bear Cr.	Bc1.0	1548
Bear Cr.	Bc2.0	1622
Bear Cr.	Bc3.4	1658
Bear Cr.	Bc4.0	1817
Bear Cr.	Bc4.1	1817
Bear Cr.	Bc4.8	1926
Bear Cr.	Bc5.4	1999
Bear R.	Br5.0	1524
Bear R.	Br6.0	1536
Bear R.	Br8.0	1585
Bear R.	Br9.5	1707
Bear R.	Br12.0	2073
Ballentyne Cr.	Bal0.0	1859
Ballentyne Cr.	Bal0.5	1905
Ballentyne Cr.	Bal1.5	1981
Ballentyne Cr.	Bal1.9	1987
Ballentyne Cr.	Bal2.1	1999
Big Silver Cr.	Bs2.2	1914
Crooked R.	Cr14.8	1707
Crooked R.	Cr15.9	1815
Crooked R.	Cr20.0	1902
Crooked R.	Cr21.6	1939
Crooked R.	Cr22	1951
Crooked R.	Cr24	2009
Crooked R.	Cr25.5	2048
Cub Cr.	Cu0.0	1707
Johnson Cr.	J0.0	1707
Johnson Cr.	J1.0	1731
Johnson Cr.	J2.0	1768
Johnson Cr.	J3.0	1817
Johnson Cr.	J4.0	1871
Johnson Cr.	J5.0	1908
Johnson Cr.	J6.0	1932
Johnson Cr.	J7.0	1957
Little Silver Cr.	Ls0.0	1890
Lodgepole Cr.	Ldg0.0	1890
Lodgepole Cr.	Ldg0.5	1743
McLeod Cr.	Mclod0	2006
McLeod Cr.	Mclod1.0	2048
McPhearson Cr.	McPh0.0	2040
McPhearson Cr.	McPh1.0	2121
North Fork Boise R.	NFB36.5	1914
North Fork Boise R.	NFB37.5	1942
North Fork Boise R.	NFB39	1987
North Fork Boise R.	NFB40	1948
North Fork Boise R.	NFB40.4	2018
North Fork Boise R.	NFB40.5	2030
Pike's Fork Cr.	PF 1.0	1804
Rocky Cr.	Rc0.0	1585
Sawmill Cr.	Saw0.0	1646
West Fork Cr.	Wf0.0	1975
Willow Cr.	Wil0.0	1646

APPENDIX F

Time of Day and Direction of Fish Captured at the Weir Trap in 1999 and 2000

Table 1.F Weekly Weir Capture Diel patterns, 2000

Time Periods: Night time period: 24:00-7:00 hours Day time period: 7:00-17:00 hours Twilight time period: 17:00-24:00 hours	8/31-9/7	9/8-9/14	9/15-9/21	9/22-9/28	9/29-10/5	10/6-10/12	10/13-10/21	Total	**Capture total**
Largescale Sucker-night	1	0	0	0	0	0	0	1	**2**
day	0	0	0	0	0	0	0	0	
twilight	0	0	0	0	1	0	0	1	
Bull Trout-night	53	58	37	7	37	36	9	237	**434**
day	2	6	3	4	6	1	1	23	
twilight	7	38	28	25	22	47	7	174	
Rainbow Trout-night	53	13	12	6	5	1	0	90	**127**
day	11	6	3	1	1	0	0	22	
twilight	5	4	2	4	0	0	0	15	
Pike Minnow-night	1	0	0	0	0	0	0	1	**7**
day	1	1	0	0	0	0	0	2	
twilight	2	0	2	0	0	0	0	4	
Whitefish-night	30	7	0	7	0	9	9	62	**123**
day	8	5	1	3	0	13	12	42	
twilight	2	6	0	0	0	6	5	19	
Cutthroat Trout-night	0	0	0	0	0	0	0	0	**1**
day	0	0	0	0	0	0	1	1	
twilight	0	0	0	0	0	0	0	0	
Week totals	*176*	*144*	*88*	*57*	*72*	*113*	*44*		**694**

Table 2.F Weekly Weir Captures, Direction of Travel 1999.

	8/27-9/12	**9/13-9/22**	**9/22-9/29**	**9/30-10/6**	**10/6-10/12**	**10/12-10/21**	**10/21-10/26**	**Total**
Largescale Sucker-up	5	0	0	0	0	0	0	5
down	0	0	0	2	0	1	4	7
Bull Trout-up	2	3	0	2	1	4	0	12
down	13	29	50	51	69	34	8	254
Rainbow Trout-up	6	6	2	0	12	3	0	29
down	9	21	14	25	20	14	10	113
Brook Trout-up	0	0	0	0	0	0	0	0
down	2	0	0	0	0	1	0	3
Pike Minnow-up	1	0	0	0	0	0	0	1
down	8	3	0	0	3	9	8	31
Whitefish-up	13	22	9	7	9	13	21	94
down	1	2	9	6	2	10	44	74
Cutthroat Trout-up	0	0	0	0	0	0	0	0
down	0	0	0	1	0	0	1	2
Week totals	*60*	*86*	*84*	*94*	*116*	*89*	*96*	